16

MCDONNELL DOUGLAS

SPACE TUG SYSTEMS STUDY (CRYOGENIC)
SEPTEMBER DATA DUMP

VOLUME 6 Operations
Book 3 Option 3

SEPTEMBER 1973

PREPARED BY: SPACE TUG STUDY TEAM

APPROVED BY: L. Q. Westmoreland

L. Q. WESTMORELAND
STUDY MANAGER

(NASA-CR-179112) SPACE TUG SYSTEMS STUDY (CRYOGENIC). VOLUME 6: OPERATIONS, BOOK 3, OPTION 3 Data Dump, Sep. 1973 (McDonnell-Douglas Astronautics Co.) 1358 p Avail: NTIS

N87-70400

Unclas
00/18 0074237

PREPARED FOR NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MARSHALL SPACE FLIGHT CENTER
UNDER CONTRACT NO. NAS8-29677

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY-WEST

5301 Bolsa Avenue, Huntington Beach, CA 92647

MCDONNELL DOUGLAS

SPACE TUG SYSTEMS STUDY (CRYOGENIC)
SEPTEMBER DATA DUMP

VOLUME 6 Operations
Book 3 Option 3

SEPTEMBER 1973

PREPARED BY: SPACE TUG STUDY TEAM

APPROVED BY: L. Q. Westmoreland

L. Q. WESTMORELAND
STUDY MANAGER

PREPARED FOR NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MARSHALL SPACE FLIGHT CENTER
UNDER CONTRACT NO. NAS8-29677

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY-WEST

5301 Bolsa Avenue, Huntington Beach, CA 92647

PREFACE

This study report for the Tug Program is submitted by the McDonnell Douglas Astronautics Company (MDAC) to the Government in partial response to Contract Number NAS8-29677.

The current results of this study contract are reported in eight volumes:

Volume 1 — Summary, Program Option 1

Volume 2 — Summary, Program Option 2

Volume 3 — Summary, Program Option 3

These three summary volumes present the highlights of the comprehensive data base generated by MDAC for evaluating each of the three program options. Each volume summarizes the applicable option configuration definition, Tug performance and capabilities, orbital and ground operations, programmatic and cost considerations, and sensitivity studies. The material contained in these three volumes is further summarized in the Data Dump Overview Briefing Manual.

Volume 4 — Mission Accomplishment. (3 Books and 1 Supplement Bound Together)

This volume contains mission accomplishment analysis for each of the three program options and includes the tug system performance, mission capture, and fleet size analysis.

Volume 5 — Systems (3 Books)

This volume presents the indepth design, analysis, trade study, and sensitivity technical data for each of the configuration options and each of the Tug systems i.e., structures, thermal, avionics, and propulsion. Interface with the Shuttle and Tug payloads for each of the three options is defined.

Volume 6 – Operations (3 Books)

This volume presents the results of orbital and ground operations trades and optimization studies for each option in the form of operations descriptions, time lines, support requirements (GSE, manpower, networks, etc.), and resultant costs.

Volume 7 – Safety (3 Books)

This volume contains safety information and data for the Tug Program. Specific safety design criteria applicable to each option are determined and potential safety hazards common to all options are identified.

Volume 8 – Programmatics and Cost (3 Books)

This volume contains summary material on Tug Program manufacture, facilities, vehicle test, schedules, cost, project management SR&T, and risk assessment for each option studied.

These volumes contain the data required for the three options which were selected by the Government for this part of the study and are defined as:

A. Option 1 is a direct development program (I.O.C.: Dec 1979). It emphasizes low DDT&E cost; the deployment requirement is 3500 pounds into geosynchronous orbit, it does not have retrieval capability, and it is designed for a 36-hour mission. MDAC has also prepared data for an alternative to Option 1 which deviates from certain requirements to achieve the lowest practicable DDT&E cost.

B. Option 2 is also a direct development program (I.O.C.: 1983). It emphasizes total program cost effectiveness in addition to low DDT&E cost. The deployment requirement is 3500 pounds minimum into geosynchronous orbit and 3500 pounds minimum retrieval from geosynchronous orbit.

C. Option 3 is a phased development program (I.O.C.: 1979 phased to I.O.C. 1983). It emphasizes minimum initial DDT&E cost and low total program cost. The initial Tug capability will deploy a minimum of

3500 pounds into geosynchronous orbit without retrieval capability, however, through phased development, it will acquire the added capability to retrieve 2200 pounds from geosynchronous orbit. The impact of increasing the retrieval capability to 3500 pounds is also provided.

CONTENTS

VOLUME 6 OPERATIONS

OPTION 3

1.0 CONFIGURATION SUMMARY

- **DESIGN**

STRUCTURE

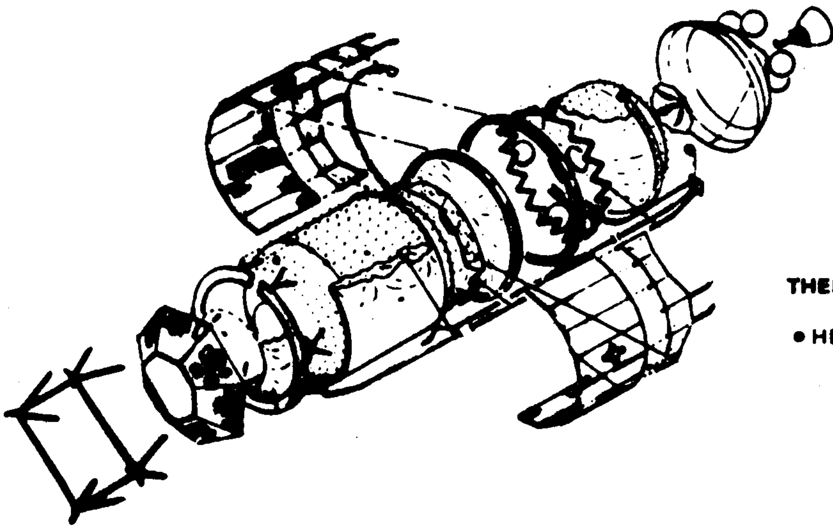
- LO_2 / LH_2 TANK: 2219 TAPER
- OUTER SHELL: AL - ISOGRID
- THRUST STRUCT: FG ISOGRID
- TANK SUPPORTS: FG TUBE

AVIONICS

- COMPUTER: REDUNDANT 16 BIT, 16 K WDS
- GUID / NAV: .0 3° STAR TRACKER
- POWER: BATTERIES 646 WATTS (TUG) 0 (TO P/L)

PROPULSION

- CATEGORY I RL-10 5.5: 1 EMR 441.8 ISP
- PRESS: AMB. HE
- APS: MONO-PROP



THERMAL CONTROL

- HEAT PIPE PANEL

SIZE

- DRY WEIGHT: 6309 LB
- LENGTH [illegible] 3 IN.
- DIA 176 [illegible]
- LO_2 42,865 LB
- LH_2 7,894 LB

PERFORMANCE

- MISSION DURATION: 1.5 DAYS
- P / L DEPLOY: 4360 LB
- ROUNDTRIP: 1630 LB
- AUTONOMY LEVEL: IV
- PLACEMENT ACCURACY: 34.9 N. MI.

PROGRAM DESCRIPTION

- IOC: DEC 31 1979
- DEVELOPMENT TIME TO IOC: 51 MO
- FLEET SIZE: 4
- NO. OF FLTS: ETR / WTR: 74 / 8
- PROG. COST:

  DDT & E: TBD
  INVEST.: TBD
  OPS.: TBD

Figure 1. Configuration Summary Option 31

● DESIGN

STRUCTURE

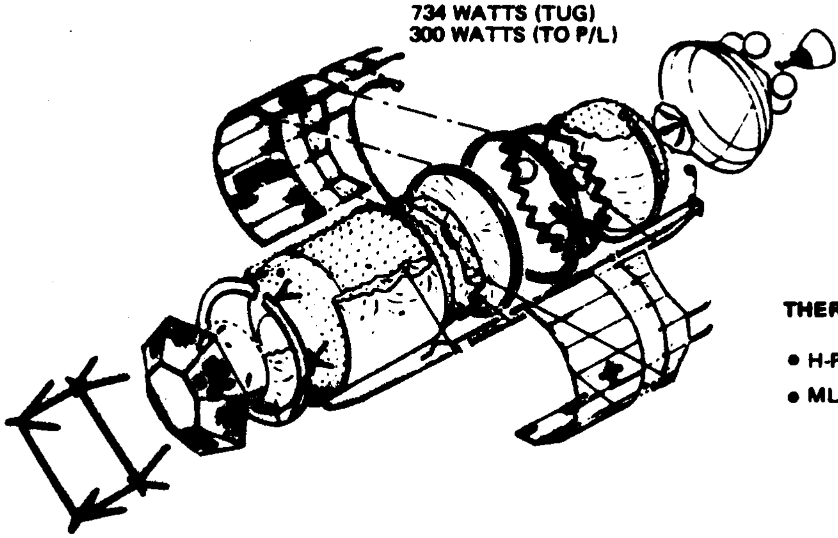
- LO_2 / LH_2 TANK: 2219 TAPER
- OUTER SHELL: AL - ISOGRID
- THRUST STRUCT: FG ISOGRID
- TANK SUPPORTS: FG TUBE

AVIONICS

- COMPUTER: REDUNDANT 16 BIT, 16 K WDS
- GUID / NAV: $.03^{\circ}$ STAR TRACKER
- RENDZ. & DOCK: LASER RADAR
- POWER: FUEL CELLS 734 WATTS (TUG) 300 WATTS (TO P/L)

PROPULSION

- CATEGORY I RL-10 5.5: 1 EMR 441.8 ISP
- PRESS: COLD HE
- APS: BI-PROP



THERMAL CONTROL

- H-PIPE PANEL
- MLI

SIZE

- DRY WEIGHT: 6098 LB
- LENGTH: 407.3 IN.
- DIA: 176 IN.
- LO_2: 47,363 LB
- LH_2: 7,894 LB

PERFORMANCE

- MISSION DURATION: 6 DAYS
- P/L DEPLOY: 6890 LB
- ROUNDTRIP: 4140 LB
- AUTONOMY LEVEL: III
- PLACEMENT ACCURACY: 69.7 N. MI.

PROGRAM DESCRIPTION

- IOC: DEC 31 1983
- DEVELOPMENT TIME TO IOC: 51 MO.
- FLEET SIZE: 8
- NO. OF FLTS: ETR / WTR: 234 / 50
- PROG. COST:
  - DDT & E: TBD
  - INVEST.: TBD
  - OPS.: TBD

Figure 2. Configureation Summary Option 3F

2.0 Orbital Operations Summary

The following paragraphs summarize the orbital operations of the tug and associated ground support of orbital ops.

2.1 Mission Performance

The performance capability was computed for each mission in the mission model and for each mission mode - deploy, retrieve, round trip and expendable. Table 2.1-1 summarizes the general mission descriptions. The performance results are given in Tables 2.1-2 through -4 for options 3I, 3F and 3S. A discussion of the derivation and applications of these data is presented in Volume IV, Sections 1.1, 1.4, and 1.5.

/

Table 2.1-1

MISSION DESCRIPTIONS

Mission No.	$H_a \times H_p$ (nmi)	Incl.	Remarks
1-8	19323	0	Synchronous orbit - single burn transfer orbit injection
1-8A	19323	0	Synchronous orbit - two burn transfer injection
1-8B	19323	0	Synchronous orbit - two burn transfer injection with 600 fps for multiple payload deployments
9	1AU	Eclip.	
10	6900	55°	
10A	6900	55°	Alternate - Shuttle launched into 28.5°
11	16Kx30K	20°	
12	180x1800	90°	
13	1Kx20K	90°	
13A	1Kx20K	90°	ETR Alternate - Shuttle launched into 28.5°
13B	1Kx20K	90°	ETR Alternate - Shuttle launched into 55°
14	300x3000	90°	
15	700	100°	
16	500	99.2°	
17-8	Interplanetary		ΔV - 13000
19			16500
20			23000
21-2			24000
23			18400
24			22000
D11	58K	0,30,60	
D10	860x21K	63.4	Shuttle launch into 63.4° WTR
D10A	860x21K	63.4	ETR Alternate - Shuttle launched into 55°
D5	750	99°	
D3	13.6Kx25K	60°	Shuttle launched into 60° WTR
D3A	13.6x25K	60°	ETR Alternate - Shuttle launched into 55°
D12	300	104°	
D16	400	98.3°	

Table 2.1-2

CØNFIGURATIØN ØPT 31 STAGE WT=7315.00 ISP=441.80 DELISP=4.00

MISSIØN	GRØSS-WT V-ØUT	PL-RØUND V-BACK	PL-DEPLØY	PL-RETRIEVE	PL-EXPEND
1-8	62665.00 13972.00	1335.76 13920.00	3588.51	2127.81	15925.11
1-8A	62665.00 13890.00	1386.27 13920.00	3724.20	2208.27	16060.79
1-8B	62665.00 14190.00	1023.42 14220.00	2808.60	1610.15	15568.22
9	62665.00 14160.00	964.44 14350.00	2671.27	1509.40	15617.01
10	50665.00 9700.00	5465.99 9700.00	10882.80	10981.61	18131.98
10A	62665.00 12760.00	2922.37 12760.00	7230.27	4904.86	18013.35
11	62665.00 12450.00	3383.05 12450.00	8187.84	5765.07	18576.96
12	32665.00 2285.00	16299.57 2285.00	19170.24	108848.31	20458.55
13	[illegible] 8400.00	2595.66 8400.00	4712.36	5778.68	10677.55
13A	62665.00 13460.00	1953.80 13460.00	5080.21	3174.80	16785.40
13B	50665.00 11200.00	3014.24 11200.00	6675.72	5495.66	15561.43
14	32665.00 3600.00	12277.56 3600.00	15852.87	54438.61	17983.04
15	26665.00 1700.00	13631.58 1700.00	15380.14	119901.62	16318.46
16	26665.00 1120.00	15429.58 1120.00	16706.52	201869.75	17311.90
17-8	62665.00 13140.00	2309.20 13250.00	5915.44	3787.85	17339.18
19	62665.00 16740.00	.00 17210.00	.00	.00	11778.93

20	62665.00 23550.00	.00 24500.00	.00	.00	4459.11
21-2	62665.00 24600.00	.00 25500.00	.00	.00	3613.35
23	62665.00 18720.00	.00 19550.00	.00	.00	9275.04
24	62665.00 22500.00	.00 23500.00	.00	.00	5370.34
D11	62665.00 13930.00	1355.44 13930.00	3643.95	2158.24	15994.50
D10	48665.00 8500.00	7241.95 8500.00	13241.24	15983.95	19301.04
D10A	50665.00 9800.00	5285.80 9800.00	10599.03	10544.33	17951.97
D5	26665.00 1770.00	13424.42 1770.00	15221.87	113686.00	16201.30
D3	48665.00 11850.00	1731.80 11850.00	4016.62	3044.46	13667.44
D3A	50665.00 11920.00	2010.46 11920.00	4686.13	3521.09	14421.47
D12	26665.00 500.00	17522.61 500.00	18155.77	502460.00	18420.09
D16	26665.00 850.00	16318.48 850.00	17333.52	278667.12	17788.52

Table 2.1-3

CØNFIGURATIØN ØPT 3F   STAGE WT=7039.00   ISP=441.80   DELISP=4.00

MISSIØN	GRØSS-WT V-ØUT	PL-RØUND V-BACK	PL-DEPLØY	PL-RETRIEVE	PL-EXPEND
1-8	62665.00 13972.00	1611.76 13920.00	4329.98	2567.46	16201.11
1-8A	62665.00 13890.00	1662.27 13920.00	4465.66	2647.92	16336.79
1-8B	62665.00 14190.00	1299.42 14220.00	3566.03	2044.38	15844.22
9	62665.00 14160.00	1240.44 14350.00	3435.72	1941.36	15893.01
10	50665.00 9700.00	5741.99 9700.00	11432.32	11536.12	18407.98
10A	62665.00 12760.00	3198.37 12760.00	7913.12	5368.09	18289.35
11	62665.00 12450.00	3659.05 12450.00	8855.83	6235.41	18852.96
12	32665.00 2285.00	16575.57 2285.00	19494.85	110691.44	20734.55
13	32665.00 8400.00	2871.66 8400.00	5213.43	6393.13	10953.55
13A	62665.00 13460.00	2229.80 13460.00	5797.86	3623.29	17061.40
13B	50665.00 11200.00	3290.24 11200.00	7286.98	5998.87	15837.43
14	32665.00 3600.00	12553.56 3600.00	16209.24	55662.39	18259.04
15	26665.00 1700.00	13907.58 1700.00	15691.55	122329.31	16594.46
16	26665.00 1120.00	15705.58 1120.00	17005.36	205480.75	17587.90
17-8	62665.00 13140.00	2585.20 13250.00	6622.46	4240.58	17615.18
19	62665.00 16740.00	.00 17210.00	.00	.00	12054.93

20	62665.00 23550.00	.00 24500.00	.00	.00	4735.11
21-2	62665.00 24600.00	.00 25500.00	.00	.00	3889.35
23	62665.00 18720.00	.00 19550.00	.00	.00	9551.04
24	62665.00 22500.00	.00 23500.00	.00	.00	5646.34
D11	62665.00 13930.00	1631.44 13930.00	4385.95	2597.71	16270.50
D10	48665.00 8500.00	7517.95 8500.00	13745.88	16593.12	19577.04
D10A	50665.00 9800.00	5561.80 9800.00	11152.46	11094.91	18227.97
D5	26665.00 1770.00	13700.42 1770.00	15534.83	116023.31	16477.30
D3	48665.00 11850.00	2007.80 11850.00	4656.75	3529.66	13943.44
D3A	50665.00 11920.00	2286.46 11920.00	5329.45	4004.47	14697.47
D12	26665.00 500.00	17798.61 500.00	18441.75	510374.31	18696.09
D16	26665.00 850.00	16594.48 850.00	17626.68	283380.31	18064.52

Table 2.1-4

CØNFIGURATIØN ØPT 3S   STAGE WT=6840.00 ISP=462.20 DELISP=4.00

MISSIØN	GRØSS-WT V-ØUT	PL-RØUND V-BACK	PL-DEPLØY	PL-RETRIEVE	PL-EXPEND
1-8	62665.00 13972.00	2608.05 13920.00	6704.89	4268.34	17449.45
1-8A	62665.00 13890.00	2660.75 13920.00	6840.37	4354.59	17584.93
1-8B	62665.00 14190.00	2281.84 14220.00	5986.85	3687.18	17092.91
9	62665.00 14160.00	2220.16 14350.00	5876.64	3568.23	17141.66
10	50665.00 9700.00	6749.23 9700.00	13032.00	13999.58	19399.26
10A	62665.00 12760.00	4257.38 12760.00	10116.85	7350.73	19530.77
11	62665.00 12450.00	4734.06 12450.00	11015.48	8301.93	20091.18
12	32665.00 2285.00	17118.16 2285.00	19988.11	119221.62	21134.87
13	32665.00 8400.00	3611.15 8400.00	6384.18	8313.75	11636.66
13A	62665.00 13460.00	3251.99 13460.00	8103.52	5431.81	18307.86
13B	50665.00 11200.00	4247.07 11200.00	9078.95	7980.14	16860.77
14	32665.00 3600.00	13203.56 3600.00	16855.63	60939.31	18747.55
15	26665.00 1700.00	14332.89 1700.00	16084.77	131597.75	16920.79
16	26665.00 1120.00	16066.18 1120.00	17334.34	219608.87	17874.23
17-8	62665.00 13140.00	3621.42 13250.00	8896.45	6107.61	18859.71
19	62665.00 16740.00	.00 17210.00	.00	.00	13291.43

20	62665.00 23550.00	.00 24500.00	.00	.00	5843.98
21-2	62665.00 24600.00	.00 25500.00	.00	.00	4971.98
23	62665.00 18720.00	.00 19550.00	.00	.00	10761.29
24	62665.00 22500.00	.00 23500.00	.00	.00	6780.35
D11	62665.00 13930.00	2628.59 13930.00	6762.27	4300.09	17518.75
D10	48665.00 8500.00	8520.52 8500.00	15166.02	19445.12	20500.81
D10A	50665.00 9800.00	6566.13 9800.00	12764.74	13521.58	19221.88
D5	26665.00 1770.00	14132.77 1770.00	15935.67	124918.75	16808.23
D3	48665.00 11850.00	2910.54 11850.00	6502.31	5269.06	14943.25
D3A	50665.00 11920.00	3215.31 11920.00	7217.38	5798.54	15731.05
D12	26665.00 500.00	18076.26 500.00	18699.84	542067.44	18935.80
D16	26665.00 850.00	16920.80 850.00	17925.08	302013.50	18331.05

MISSION DURATION

One of the factors affecting flight operations effort (or cost) is mission duration. Since there are many different types of missions which vary in time on orbit and since some of the ground support tasks are proportional to mission duration it was necessary to calculate a time for each mission required by the mission model. This was done by using the timelines for the reference missions. The ground rules for computing these times and a list of missions with the calculated time for each are shown below. In order to simplify the computer programming for the flight operations cost runs the specific mission times for all the missions flown for a given year were averaged to produce a single number for that year which would provide the proper results.

GROUND RULES FOR COMPUTING MISSION TIMES FROM THE REFERENCE MISSION TIMELINES

Mission time is defined as the total elapsed time from Shuttle launch to Orbiter landing.

1. For Option 1 and Initial Phase of Option 3:
   a. For dedicated missions the Tug on orbit time (from Orbiter deployment to Orbiter retrieval) is 36 hours.

   b. For multiple deployments all payloads are deployed simultaneously.

   c. There is no retrieval missions.

2. For Option 2 and the Final Phase of Option 3:
   a. For the roundtrip mission the deployment and retrieval are in the same location.

   b. For dedicated missions the Tug on orbit time is 6 days.

   c. For multiple deployments, payloads are deployed in the same orbit with 2 revolutions to obtain 60° orbital separation.

   d. For multiple deployments with retrieval, payloads are deployed as above and the retrieved payload is in the same location as the last deployment.

   e. Rendezvous and docking requires 6 hours.

   f. Payload spin-up requires 1/2 hour.

ORBIT	NO.	SYM	MISSION	OPTION 1 TIME (HRS)	OPTION 2
Synchronous Equatorial	(1)	A	Single Deployment	43	43
"	(2)	A(2)	Double Deployment	43	91
"	(3)	A(3)	Triple Deployment	43	139
"	(4)	AE	One Deployment - Expend Tug	21	21
"	(5)	AB	Roundtrip-Deploy one, Retrieve one	20	43
"	(6)	BA	Dedicated	48	156
"	(7)	A(2)B	Deploy two, Retrieve one	-	91
"	(8)	A(3)B	Deploy Three, Retrieve one	-	139
"	(9)	B	Retrieve one	-	43
Low ΔV	(10)	A	Single Deployment	23	23
High Inclination "	(11)	A(2)	Double Deployment	23	23
	(12)	A(3)	Triple Deployment	23	23
"	(13)	AB	Round Trip	23	23
"	(14)	BA	Dedicated	42	150
"	(15)	A(2)B	Deploy Two, Retrieve One	-	23
"	(16)	B	Retrieve One	-	23
High ΔV	(17)	A	Single Deployment	35	40
Med. Inclination	(18)	A(2)	Double Deployment	35	40
"	(19)	A(3)	Triple Deployment	35	40
"	(20)	AE	One Deployment - Expend Tug	15	15
"	(21)	AB	Roundtrip	-	40
"	(22)	A(3)B	Deploy Three, Retrieve One	-	40
"	(23)	B	Retrieve One	-	40
Planetary	(24)	A	Single Deployment	32	32
"	(25)	A(2)	Double Deployment	32	32
"	(26)	AE	One Deployment - Expend Tug	10	10

Mission Model Capture

Mission model capture analysis involved the assigning of each payload in the mission model to specific flights. The assignment involved consideration of tug capabilities (availability, payload weight, maneuver capability, and mission duration capability), Shuttle constraints (availability, cargo bay dimensions, payload weight and launch constraints) and payload characteristics (weight, physical dimensions, launch schedule, mission constraints such as DOD mission modes). Payloads were combined to minimize the number of tug flights necessary to perform all of the missions identified in the mission model.

The Flight Summary is shown in Table 2.1-3. Out of 558 missions the Option 3 Tug performs 525 and requires 366 flights to accomplish them. The 33 missed flights are due to the Shuttle limit of 3 Tug missions in 1980 and 21 Tug missions in 1981.

FLIGHT SUMMARY-OPTION TOTAL-OPTION 3

Flight Mode		80	81	82	83	84	85	86	87	88	89	90	Total
		Calendar Year											
Totals	Shuttle	3	21	22	36	44	41	41	40	37	41	40	366
	Tug	3	21	22	36	44	41	41	40	37	41	40	366
Tug Flight Distribution	Deploy												
	Single Payload	2	21	18	25	12	14	7	10	7	12	10	138
	Multi--2 Payloads	1		2	8		1	1	5	4	4	1	27
	Multi--3 Payloads				1	2	1	1	1	1	2	2	11
	Kick-Stage Mode			2	1	2		3	2				10
	Expendable					2		1	1		3	1	8
	Retrieve												
	Single Payload					12	9	12	8	9	8	11	69
	Round Trip												
	Deploy 1/Retrieve 1					13	14	16	11	16	10	15	95
	Deploy Multi/Retrieve 1					1	1		1		1		4
	Sortie				1		1		1		1		4
Mission Model	Total												
	Deploy	34	23	24	48	37	37	32	41	34	43	34	387
	Retrieve	0	0	0	1	25	25	28	21	25	20	26	171
	Total	34	23	24	49	62	62	60	62	59	63	60	558
Accomplishment	Total	3	21	24	49	62	62	60	62	59	63	60	525

ACPS Capabilities - Option 3I

Option 3I ACPS requirements are to provide 3 degree of freedom attitude control and a limited amount of axial ΔV capability. The ΔV requirement is for propellant settling and payload backoff. The selected monopropellant blowdown system has a thrust range of 27-16 lbs and provides the following control characteristics.

	Pitch/Yaw Acceleration	Roll Acceleration	Pitch Yaw Minimum Limit Cycle Rate	Roll Minimum Limit Cycle Rate
Min	$.135^{\circ}/d^2$	$1.78^{\circ}/s^2$	$.002^{\circ}/s$	$.027^{\circ}/s$
Max	$.581^{\circ}/s^2$	$2.67^{\circ}/s^2$	$.009^{\circ}/s$	$.04^{\circ}/s$

$\leq 0.1^{\circ}/s$ Required

Total impulse requirements for the Option 1 vehicle are 13200 lb sec for attitude control and 34400 for propellant settling giving a total of 47600 lb sec which is well within the 65000 lb sec capacity of the selected ACPS tankage.

ACPS Capabilities - Option 3F

Option 3F ACPS requirements are to provide 3 degree of freedom attitude control, 3 degree of freedom translation control, and axial ΔV capability. The selected bipropellant system has 100 lb axial thrustors and 25 lb tangential thrusters and provides the following attitude control characteristics:

	Pitch/Yaw Acceleration	Roll Acceleration	Pitch Yaw Limit Cycle Rate	Roll Limit Cycle Rate
Min	$.321^{\circ}/s^2$	$2.0^{\circ}/s^2$	$.005^{\circ}/s$	$.03^{\circ}/s$
Max	$4.0^{\circ}/s^2$	$3.65^{\circ}/s^2$	$.06^{\circ}/s$	$.055^{\circ}/s$

$\leq 0.1^{\circ}/s$ required

Translation and ΔV

	Axial Acceleration	Lateral Acceleration	Control/Disturbance Moment During Lateral Acceleration
Min	.2 ft/sec^2	-	-
Max	1.8 ft/sec^2	-	-
Synch Retrieval			
	.34 or .68 ft/sec^2	.17 ft/sec^2	6.5:1 (> 2:1 desired)

Total impulse requirements for Option 3F are 73000 lb sec for attitude control and ΔV and 85000 lb sec for propellant settling for a total of 158000 lb sec which is well within the 176000 lb sec capacity of the selected ACPS tankage.

2.2 Ground/Onboard Functional Requirements

FLIGHT OPERATIONS

Definition of this program option must include a description of the operational functions that must be performed by the associated Tug design/configuration. The operational concept for the autonomy level of this option, developed earlier and modified to be consistent with the latest changes, is included herein. Since the differences between autonomy levels III and IV are minor software variations, the same operational concept applies for both autonomy levels. Also, since all the configurations of the three options are based on either Level III or IV, the concept is essentially identical for all three options. First and second level functional flow diagrams for each of the four reference missions may be found in the Appendix.

Following the operational concept is a brief description of the analysis that was performed to estimate the effort and cost of the operations (recurring and non-recurring) for this option. The summary results of this analysis for both NASA and DOD are shown.

OPERATIONAL CONCEPT -- AUTONOMY LEVEL III AND IV

LAUNCH AND ASCENT

Orbiter provides environmental control, power, structural attachment and propellant venting and dump lines. Tug remains quiescent with electronic equipment in standby mode.

PRE-DEPLOYMENT CHECKOUT

Mission Support Operator (MSO) in the Orbiter activates and checks the Tug subsystems by means of the onboard automatic checkout equipment. The MSO initializes the Tug computer and aligns the Tug IMU. The MSO disconnects the vent and dump lines and releases the stowage retention devices.

TUG DEPLOYMENT AND SEPARATION

The MSO rotates the Tug out of the cargo bay to launch position. The MSO connects the manipulator to the Tug, disconnects the umbilicals, releases the base ring attachment devices, moves the Tug away from the Orbiter and releases it. The MSO activates and checks the APS, attitude control and main propulsion by RF link.

The MSO performs post separation subsystem checks by RF link to the automatic checkout equipment. The MSO transfers control to the Tug by RF link. Upon acquiring control, the Tug is programmed to maneuver to a local vertical/orbit plane orientation in preparation for the first main engine burn. An inertial orientation will generally be maintained throughout the mission except for main engine burn periods and when payload thermal requirements dictate otherwise.

PHASING, TRANSFER, AND INJECTION INTO ORBIT

The data management system (DMS) receives the propulsion burn parameters from the ground via RF uplink command sequence and executes the commands at the appropriate time to perform the required attitude maneuvers, check the subsystems readiness and make the main engine burn. The velocity increment actually measured along with other pertinent data is reported by RF downlink to Mission Control. Ground tracking and computation will determine if and when midcourse corrections are necessary between principal burn locations and the degree of correction required. The appropriate burn parameters will be transmitted to the Tug by RF uplink command and executed by the DMS at the designated time.

PAYLOAD DEPLOYMENT AND SEPARATION

Prior to arriving at the desired location in the required orbit, Mission Control transmits an uplink command to enable payload deployment. Upon arrival at the desired location, the DMS executes a stored sequence to accomplish the following:

Activate the docking subsystem

Disconnect the payload umbilicals

Spin up the payload if required for stabilization

Release the docking ring latches to uncouple the payload

Fire APS thrusters to provide separation distance

Deactivate the docking subsystem including the spin mechanism.

Upon completion of deployment, the DMS is programmed to report accomplishment to Mission Control. Mission Control then transmits commands to initiate the next phase of the mission operation.

RENDEZVOUS AND DOCKING

After the appropriate burns and coast periods to place the Tug within normal rendezvous range of the payload, Mission Control will compare the relative orbital positions of the Tug and payload, as determined by ground tracking, calculate the azimuth from the Tug to the payload and command the proper orientation of the Tug to permit acquisition of the payload by the rendezvous sensor (laser radar). The rendezvous sensor will acquire and lock on to the payload which is passive. In the event the Tug has no rendezvous sensor, this azimuth pointing is not necessary. Mission Control will ascertain by RF link whether the payload is ready for rendezvous.

The rendezvous sensor provides range, range rate, and angular line of sight data to the data management system which transmits it to the ground for computation of the rendezvous intercept maneuvers and the terminal phase initial burn parameters. Upon receipt of an uplink command sequence, the data management system commands the Tug to maneuver to the required attitude, checks subsystem readiness and commands the APS burn to acquire velocity for target payload intercept. After the designated coast period the data management system will command an APS burn to decelerate the Tug. For the Tug without the rendezvous sensor, the terminal phase initial burn and subsequent deceleration will be determined solely on ground tracking data.

During the coast period, Mission Control will verify the payload readiness for docking by RF link and command activation of the docking subsystem.

The range, range rate, and angular data from the sensor will be used by Mission Control to determine final intercept maneuvers, compute the terminal phase final burn parameters and determine the payload docking mechanism orientation. Without a rendezvous sensor, the final maneuvers and burn parameters must be ground computed from tracking data until docking sensor acquisition is obtained.

During final target closure the docking sensor will determine the docking structure orientation and the APS impulse sequences required to maneuver the vehicle to a position along the docking axis at the desired precontact range will be commanded. At this point the sensor will verify proper docking alignment and the APS system will maintain this attitude orientation while providing the desired closure velocity through contact. If the payload is spinning, the Tug docking ring is spun up to an equivalent rate before docking occurs.

After contact is established, payload subsystems are passivated and the payload is de-spun by the docking ring drive. When the payload rotation has been sufficiently slowed indexing will be accomplished to stop it in the proper position so that umbilicals can be reconnected. The payload will be safed and configured for return while the Tug is maneuvered to the proper orientation for initiation of the next phase of the mission operation.

RENDEZVOUS WITH ORBITER

The Tug will be returned to the proper orbit for rendezvous with the Orbiter and will assume a stationkeeping/passive role during the rendezvous.

After communication is established, Tug control will be transferred to the Orbiter but attitude control will be automatically maintained.

As the Orbiter closes on the Tug, Tug subsystems will be deactivated and safed prior to attachment for retrieval.

When the Tug has been resecured to the base ring and retracted into the cargo bay, the umbilicals and vent lines are reconnected and the Orbiter again provides basic services to the Tug during reentry, descent and landing.

2.3 ORBITAL OPERATIONS COSTS

ORBITAL OPERATIONS COSTS ARE PRESENTED IN THIS SECTION IN TERMS OF MANHOURS AND COMPUTER HOURS FOR THE FOLLOWING WBS ITEMS:

PHASES

- WBS 32A DESIGN, DEVELOPMENT, TEST & EVALUATION (DDT&E) PHASE (NON-RECURRING)
- WBS 32C OPERATIONAL PHASE (RECURRING)

LEVEL 4

- FLIGHT OPERATIONS, NASA
- FLIGHT OPERATIONS, DOD

LEVEL 5 (SAME FOR EACH LEVEL 4)

- MISSION PLANNING
- FLIGHT CONTROL
- FLIGHT EVALUATION
- FLIGHT SUPPORT SOFTWARE

FLIGHT OPERATIONS (NASA)/(DOD)

DDT&E (NON-RECURRING) (32A-11/12)

MISSION PLANNING
32A-11/12-01

- PERFORM MALFUNCTION ANALYSIS & PREPARE CONTINGENCY PROFILES
- PREPARE ABORT PROFILES
- DEVELOP FLIGHT MISSION RULES & SUPPORTING DATA
- PREPARE COMMAND HANDBOOK
- PREPARE SYSTEM PROCEDURES & CHECKLISTS
- PREPARE FLIGHT INSTRUMENTATION LIST
- PREPARE FLIGHT CONTROL OPERATIONAL DATA BOOK
- PREPARE SYSTEM SCHEMATICS
- PREPARE INTERFACE DRAWINGS
- PLAN ALL SCHEDULES

FLIGHT CONTROL
32A-11/12-02

- PERFORM OPERATIONS PLANNING & TRAINING

FLIGHT EVALUATION
32A-11/12-03

- NOT APPLICABLE

FLIGHT SUPPORT SOFTWARE
32A-11/12-04

- DEVELOP COMPUTER PROGRAM FOR MISSION PLANNING
- DEVELOP COMPUTER PROGRAM FOR FLIGHT CONTROL
- DEVELOP FLIGHT OPERATION SIMULATION PROGRAM
- PREPARE SHUTTLE FLIGHT SUPPORT SOFTWARE
- DEVELOP ON BOARD FLIGHT OPERATION SOFTWARE
- DEVELOP POST FLIGHT EVALUATION SOFTWARE

FLIGHT OPERATIONS (NASA)/(DOD)

OPERATIONS (RECURRING) (32C-11/12)

MISSION PLANNING 32C-11/12-01

- PREPARE FLIGHT PLAN, TRAJECTORIES, TIMELINE, ETC.
- PERFORM MALFUNCTION ANALYSIS & PREPARE CONTINGENCY PROFILES
- PREPARE ABORT PROFILES
- PREPARE SYSTEM PROCEDURES & CHECKLISTS
- PREPARE FLIGHT INSTRUMENTATION LIST
- PREPARE INTERFACE DRAWINGS
- PLAN ALL SCHEDULES

FLIGHT CONTROL 32C-11/12-02

- DETERMINE FLIGHT CONTROL REQUIREMENTS
- RUN FLIGHT CONTROL PROGRAMS
- PERFORM REAL TIME FLIGHT CONTROL COVERAGE
- ANALYZE AND RESOLVE IN-FLIGHT ANOMALIES
- SUPPORT PRE-LAUNCH CHECKOUT
- SUPPORT LAUNCH AND TUG ACTIVATION
- OPERATE GROUND TRACKING & COMMUNICATIONS NETWORK

FLIGHT EVALUATION 32C-11/12-03

- PERFORM FLIGHT DATA REDUCTION
- PERFORM POST FLIGHT DATA ANALYSIS
- RESOLVE DATA ANOMALIES
- PREPARE FLIGHT EVALUATION REPORT

FLIGHT SUPPORT SOFTWARE 32C-11/12-04

- MISSION PLANNING SOFTWARE CHANGES
- FLIGHT CONTROL SOFTWARE CHANGES
- FLIGHT EVALUATION SOFTWARE CHANGES

SENSITIVITIES FOR FLIGHT OPERATIONS FUNCTIONS

WBS 320-11/12

WBS LEVELS	AUTONOMY LEVEL	MISSION DURATION	NUMBER OF FLIGHTS	PROGRAM DURATION	PROGRAM PHASING	RENDEZVOUS & DOCKING	SPIN-UP
MISSION PLANNING (320-11/12-01)							
o FLIGHT PLAN	N.A.	INCREASES	MULTIPLE	N.A.	N.A.	INCREASES	M.D.
o MALFUNCTION ANALYSIS	INCREASES	N.A.	N.A.	MULTIPLE	INCREASES	INCREASES	INCREASES
o ABORT PROFILES	INCREASES	N.A.	MULTIPLE	N.A.	INCREASES	INCREASES	INCREASES
o MISSION RULES	N.A.	N.A.	N.A.	MULTIPLE	INCREASES	INCREASES	INCREASES
o COMMAND HANDBOOK	DECREASES	N.A.	N.A.	N.A.	INCREASES	INCREASES	INCREASES
o PROCEDURES AND CHECKLISTS	INCREASES	N.A.	N.A.	MULTIPLE	INCREASES	INCREASES	INCREASES
o INSTRUMENTATION LIST	N.A.	N.A.	N.A.	MULTIPLE	INCREASES	INCREASES	INCREASES
o OPERATIONAL DATA BOOK	INCREASES	N.A.	N.A.	N.A.	INCREASES	INCREASES	INCREASES
o SYSTEM SCHEMATICS	INCREASES	N.A.	N.A.	N.A.	INCREASES	INCREASES	INCREASES
o INTERFACE DRAWINGS	INCREASES	N.A.	N.A.	MULTIPLE	INCREASES	INCREASES	INCREASES
o SCHEDULES	N.A.	N.A.	N.A.	MULTIPLE	N.A.	N.A.	N.A.
FLIGHT CONTROL (320-11/12/02)							
o CONTROL REQUIREMENTS	DECREASES	INCREASES	MULTIPLE	N.A.	N.A.	INCREASES	INCREASES
o CONTROL ANALYSIS	N.A.	INCREASES	MULTIPLE	N.A.	N.A.	INCREASES	INCREASES
o PLANNING	DECREASES	N.A.	N.A.	N.A.	INCREASES	INCREASES	N.A.
o FLIGHT CONTROL	DECREASES	INCREASES	MULTIPLE	N.A.	N.A.	N.A.	N.A.
o ANALYSIS ANOMALIES	DECREASES	INCREASES	MULTIPLE	N.A.	N.A.	N.A.	N.A.
o CHECKOUT	DECREASES	N.A.	MULTIPLE	N.A.	N.A.	N.A.	N.A.
o ACTIVATION	DECREASES	N.A.	MULTIPLE	N.A.	N.A.	N.A.	N.A.
FLIGHT EVALUATION (320-11/12-03)							
o DATA REDUCTION	N.A.	INCREASES	MULTIPLE	N.A.	N.A.	N.A.	N.A.
o DATA ANALYSIS	N.A.	INCREASES	MULTIPLE	N.A.	N.A.	N.A.	N.A.
o RESOLVE ANOMALIES	N.A.	INCREASES	MULTIPLE	N.A.	N.A.	N.A.	N.A.
[illegible]	N.A.	INCREASES	MULTIPLE	N.A.	N.A.	N.A.	N.A.
FLIGHT SUPPORT SOFTWARE (320-11/12-04)							
o PLANNING	N.A.	N.A.	N.A.	N.A.	N.A.	INCREASES	N.A.
o FLIGHT CONTROL	DECREASES	N.A.	N.A.	N.A.	N.A.	INCREASES	INCREASES
o SIMULATIONS	DECREASES	INCREASES	N.A.	N.A.	N.A.	INCREASES	INCREASES
o FLIGHT SUPPORT	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
o CONTROL SUPPORT	INCREASES	N.A.	N.A.	N.A.	N.A.	INCREASES	INCREASES
o FLIGHT EVALUATION	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

FLIGHT OPERATIONS COST METHODOLOGY

- ESTABLISH A BASELINE CONCEPT
  - 1 DAY MISSION
  - AUTONOMY LEVEL IV
  - 11 YEAR PROGRAM
  - CONFIGURATION 101

- DETERMINED MAN HOUR AND COMPUTER HOUR ESTIMATES
  - EXPERIENCE FROM PAST PROGRAMS

    SATURN

    THOR DELTA
  - TIME AND SKILL/COMPUTER

- MAINTAIN A MINIMUM FLIGHT OPERATIONS CREW (60 MEN) AT HOUSTON FOR NASA FLIGHTS AND A SECOND CREW AT SUNNYVALE FOR DOD FLIGHTS

- REMOVE TRACKING NETWORK COSTS AND ADD NETWORK OPERATIONAL REQUIREMENTS

FLIGHT OPERATIONS NON-RECURRING MANPOWER AND COMPUTER HOURS

WBS 32A-11/12

FLIGHT OPERATIONS TASKS	MEN	DURATION	COMPUTER HOURS
MISSION PLANNING (32A-11/12-01)			
01 MALFUNCTION ANALYSIS	5	1 YEAR	260
02 ABORT PROFILES	1	2.5 YEARS	68
03 MISSION RULES	20	2 YEARS	260
04 COMMAND HANDBOOK	5	1 YEAR	260
05 PROCEDURES AND CHECKLISTS	10	1 YEAR	---
06 INSTRUMENTATION LIST	3	1 YEAR	---
07 OPERATIONAL DATA BOOK	6	1.3 YEARS	---
08 SYSTEM SCHEMATICS	5	1 YEAR	---
09 INTERFACE DRAWINGS	7	1.5 YEARS	---
10 SCHEDULES	3	1 YEAR	43
FLIGHT CONTROL (32A-11/12-02)			
01 PLANNING	10	1.5 YEARS	---
FLIGHT SUPPORT SOFTWARE (32A-11/12-04)			
01 MISSION PLANNING	6	1 YEAR	203
02 FLIGHT CONTROL	6	2 YEARS	415
03 SIMULATIONS	15	2 YEARS	1,385
04 FLIGHT SUPPORT	3	1 YEAR	104
05 CONTROL SUPPORT	5	2 YEARS	200
06 FLIGHT EVALUATION	6	2 YEARS	415

FLIGHT OPERATIONS RECURRING MANPOWER AND COMPUTER HOURS

WBS 32C-11/12

FLIGHT OPERATIONS TASKS	MEN	DURATION	COMPUTER HOURS
MISSION PLANNING (32C-11/12-01)			
01 FLIGHT PLAN	3	1 MONTH/FLIGHT	6/FLIGHT
02 MALFUNCTION ANALYSIS	1	11 YEARS	344
03 ABORT PROFILES	1	1 MONTH/FLIGHT	2/FLIGHT
04 MISSION FLIGHT RULES	2	11 YEARS	172
05 PROCEDURES AND CHECKLISTS	2	11 YEARS	---
06 INSTRUMENTATION LIST	1	13 YEARS	---
07 PREPARE OPERATIONAL DATA BOOK	2	11 YEARS	---
08 INTERFACE DRAWINGS	2	11 YEARS	---
09 SCHEDULES	2	11 YEARS	301
FLIGHT CONTROL (32C-11/12-02)			
01 CONTROL REQUIREMENTS	2	6 WEEKS/FLIGHT	1/FLIGHT
02 CONTROL AND ERROR ANALYSIS	4	6 WEEKS/FLIGHT	5/FLIGHT
03 FLIGHT CONTROL	6	(16+MT)HOURS/FLIGHT	(16+MT)FLIGHT
04 ANALYSIS ANOMALIES	14	(16+MT)HOURS/FLIGHT	5/FLIGHT
05 CHECKOUT	20	8 HOURS/FLIGHT	8/FLIGHT
06 ACTIVATION	20	8 HOURS/FLIGHT	8/FLIGHT

FLIGHT OPERATIONS RECURRING MANPOWER AND COMPUTER HOURS

WBS 32C-11/12

F L I G H T O P E R A T I O N S T A S K S	MEN	DURATION	COMPUTER HOURS
FLIGHT EVALUATION (32C-11/12-03)			
01 DATA REDUCTION	2	2 WEEKS/FLIGHT	10/FLIGHT
02 DATA ANALYSIS	2	2 WEEKS/FLIGHT	10/FLIGHT
03 RESOLVE ANOMALIES	8	2 WEEKS/FLIGHT	2/FLIGHT
04 REPORT	3	4 WEEKS/FLIGHT	---
FLIGHT SUPPORT SOFTWARE (32C-11/12-04)			
01 MISSION PLANNING SOFTWARE CHANGES	2	11 YEARS	(32C-11/12-01)0.1
02 FLIGHT CONTROL SOFTWARE CHANGES	2	11 YEARS	(32C-11/12-02)0.1
03 FLIGHT EVALUATION SOFTWARE CHANGES	2	11 YEARS	(32C-11/12-03)0.1

RELATIVE FACTORS FOR FLIGHT OPERATION MODES

PAYLOAD SPIN UP CAPABILITY	
NOT REQUIRED	REQUIRED
1.0	1.04

RENDEZVOUS AND DOCKING	
NOT REQUIRED	REQUIRED
1.0	1.2

AUTONOMY		
LEVEL	CONTROL COMPLEXITY	DEPENDENCE ON GROUND
IV	1.0	1.00
III	1.5	.67
I	2.0	.50
II	2.5	.40

RELATIVE FACTORS FOR FLIGHT OPERATION MODES

PROGRAM DURATION	
DURATION (YRS)	DURATION VALUE
11	1.0
7	0.7
4	0.4

MISSION DURATION	
DURATION (DAYS)	DURATION VALUE
1.0	1.0
1.5	1.1
3.0	1.4
6.0	2.0

DEVELOPMENT PROGRAM	
DIRECT DEVELOPMENT	PHASED DEVELOPMENT
1.0	1.7

SYMBOLS AND NOMENCLATURE

AD	Autonomy Decrease Factor for Dependence on Ground
AI	Autonomy Increase Factor for Control Complexity
CH	Computer Hours
MD	Mission Duration Factor
MH	Man Hours
MT	Mission Time in Hours
NF	Number of Flights
NFRD	Number of Flights with Rendezvous and Docking
PD	Program Duration Factor
PP	Phased Program Factor
RD	Rendezvous and Docking Factor
SP	Spin-up Payload Capability Factor
TM	Type Mission

FLIGHT OPERATIONS

WBS 32A-11/12(DDT&E)

01 MISSION PLANNING

01 - (10,400 MH + 344 CH) AIxRDxSPxPP

02 - (5,200 MH + 68 CH) AIxRDxSPxPP

03 - (83,200 MH +344 CH) RDxSPxPP

04 - (10,400 MH + 344 CH) ADxRDxSPxPP

05 - (20,800 MH) AIxRDxSPxPP

06 - (6,240 MH) RDxSPxPP

07 - (16,640 MH) AIxRDxSPxPP

08 - (10,400 MH) AIxRDxSPxPP

09 - (20,800 MH) AIxRDxSPxPP

10 - (6,240 MH + 43 CH)

02 FLIGHT CONTROL

01 - (3,120 MH) ADxRDxPP

03 FLIGHT EVALUATION

(Not Applicable)

04 FLIGHT SUPPORT SOFTWARE

01 - (12,480 MH + 407 CH) RD

02 - (24,960 MH + 830 CH) ADxRDxSP

03 - (62,400 MH + 1,385 CH) ADxMDxRDxSP

04 - (6,240 MH + 208 CH)

05 - (41,600 MH + 746 CH) AIxRDxSP

06 - (24,960 MH + 830 CH)

FLIGHT OPERATIONS

WBS 32C-11/12 (OPERATIONS)

01 MISSION PLANNING

01 - (519 MH + 6 CH) MDxNF + (104 MH + 1.2 CH) NFRD

02 - (2080 MH + 31.3 CH) AIxRDxSPxPD

03 - (173 MH + 2 CH) AI x NF + (35 MH + 0.4 CH) AIxNFRDxSP

04 - (4160 MH + 172 CH) RDxPDxSP

05 - (4160 MH) AIxRDxSPxPD

06 - (2080 MH) PDxRDxSP

07 - (4160 MH) AIxRDxSPxPd

08 - (4160 MH) AIxRDxSPxPD

09 - (4160 MH + 27.3 CH) PD

02 FLIGHT CONTROL

01 - (480 MH + 1 CH) ADxMDxNF + (96 MH + 0.2 CH) NFRDxADxSP

02 - (960 MH + 5 CH) MDxNF + (192 MH + 1 CH) NFRDxSP

03 - [(32 + MT) 10 MH + (32 + MT) CH] ADxNF

04 - [(32 + MT) 10 MH] ADxNF

05 - (160 MH + 8 CH) ADxNF

06 - (160 MH + 8 CH) ADxNF

07 - [(16 + MT) 40 MH + (16 + MT) CH] ADxNF

03 FLIGHT EVALUATION

01 - (160 MH + 10 HC) MDxNF

02 - (160 MH + 10 CH) MDxNF

03 - (640 MH + 2 CH) MDxNF

04 - (480 MH) MDxNF

04 FLIGHT SUPPORT SOFTWARE

01 - (Mission Planning) 0.10

02 - (Flight Control) 0.10

03 - (Flight Evaluation) 0.10

MISSION CONTROL CENTER

CENTER

- SAME CONTROL CENTER AS USED FOR SPACE SHUTTLE CONTROL
- DEDICATED COMPUTER FOR DURATION OF TUG MISSION
- MISSION DURATION OF 56 HOURS (28 HOURS PRELAUNCH, 4 HOURS CONTINGENCY, FOR HOLDING, AND 24 HOURS FOR TUG MISSION TIME)

PERSONNEL

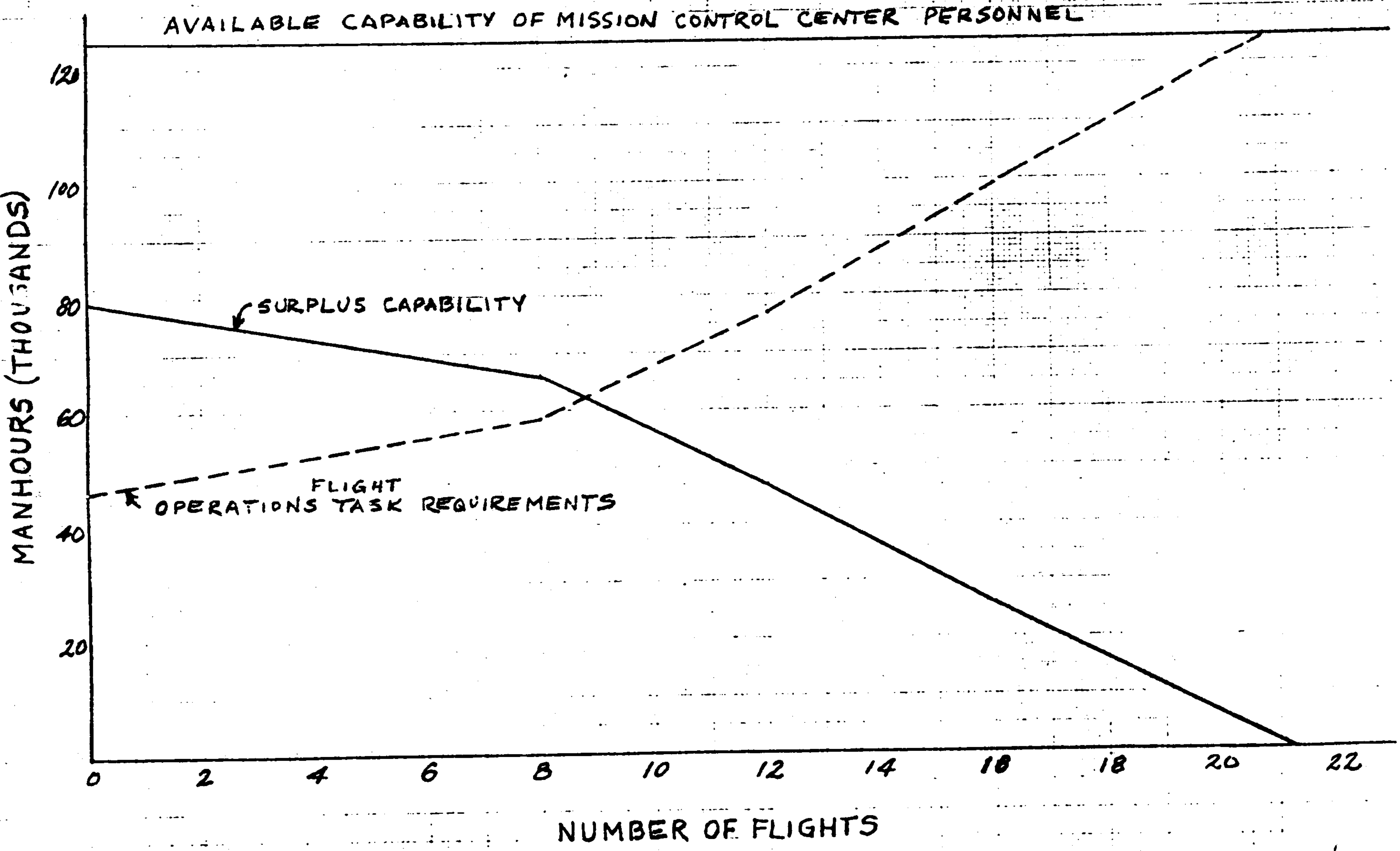
- FLIGHT DIRECTOR
- FIVE FLIGHT CONTROLLERS PER SHIFT REQUIRED FOR TUG SUBSYSTEM STATUS MONITORING STATIONS
  - TRAJECTORY & GUIDANCE (RENDEZVOUS & DOCKING)
  - PROPULSION
  - ELECTRICAL POWER
  - THERMAL & MECHANICAL
  - DATA MANAGEMENT
- 14 TECHNICAL SUPPORT PERSONNEL PER SHIFT TO RESOLVE IN-FLIGHT ANOMALIES
- TOTAL OF 20 PEOPLE PER SHIFT

FORM 28-BP-4G (REV. 6-71)

PREPARED BY: MODEL REPORT NO. REVISED

REFERENCE PAGE NO. DATE:

RELATION OF MISSION CONTROL CENTER PERSONNEL
CAPABILITY TO THE NUMBER OF FLIGHTS PER YEAR
(AUTONOMY LEVEL IV)



OPTION = 3

TOTAL PROGRAM COSTS

NUMBER OF FLIGHTS =217,[illegible]

AUTONOMY LEVEL = 3,[illegible]

NASA MISSION

LAUNCH FROM WTR = 37,[illegible]

LAUNCH FROM ETR =180,[illegible]

FLIGHT OPERATIONS RECURRING COSTS (NASA ONLY)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	3673[illegible]7,[illegible]	3388,9	9044096,4
FLIGHT CONTROL	=	819[illegible]41,[illegible]	1300[illegible],4	21350978,5
FLIGHT EVALUATION	=	3[illegible]8[illegible]1[illegible],[illegible]	4868,5	9631028,2
FLIGHT SOFTWARE	=	159465,[illegible]	2362,0	4891308,0
UNUSED MANHOURS	=	146736,1	0,0	3334722,7
TOTAL OPS, HOURS	=	1594667,7	23619,8	
TOTAL OPS, COSTS	=	35[illegible]8[illegible]022,2	9046388,9	44926411,1

OPERATIONS PER/FLT COSTS = 2[illegible]7034,2

FLIGHT OPERATIONS NON-RECURRING COSTS (TOTAL PROGRAM FOR BOTH DOD & NASA)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	478[illegible]64,[illegible]	2008,0	11543827,2
FLIGHT CONTROL	=	52263.9	0,0	1175938.2
FLIGHT EVALUATION	=	0,0	0,0	0,0
FLIGHT SOFTWARE	=	178005.2	3122.3	5200963.6
TOTAL DDT E HOURS	=	709133.7	5130.3	
TOTAL DDT E COSTS	=	15955509.0	1964904.9	17920429.0

OPTION = 3

TOTAL PROGRAM COSTS

NUMBER OF FLIGHTS =149,0

AUTONOMY LEVEL = 3,0

DOD MISSION

LAUNCH FROM WTR = 21,0

LAUNCH FROM ETR =128,0

FLIGHT OPERATIONS RECURRING COSTS (DOD ONLY)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	318094,8	2709,8	7399735,0
FLIGHT CONTROL	=	396696,2	8923,6	15331655,4
FLIGHT EVALUATION	=	327179,8	3408,2	7848924,6
FLIGHT SOFTWARE	=	124197,1	1671,3	3745026,9
UNUSED MANHOURS	=	148182,6	0,0	2963651,4
TOTAL OPS, HOURS	=	1241773,8	16712,8	
TOTAL OPS, COSTS	=	27944344,0	6400998,0	34345341,9

OPERATIONS PER/FLT COSTS = 230505,7

FLIGHT OPERATIONS NON-RECURRING COSTS (TOTAL PROGRAM FOR BOTH DOD & NASA)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	478264,6	2008,0	11543527,2
FLIGHT CONTROL	=	52263.9	0,0	1175938.2
FLIGHT EVALUATION	=	0,0	0,0	0,0
FLIGHT SOFTWARE	=	178005.2	3122.3	5200963.6
TOTAL DDT E HOURS	=	709133.7	5130.3	
TOTAL DDT E COSTS	=	15955509.0	1964904.9	17920429.0

2.4 Shuttle Interface Requirements

The Orbiter/Tug interface subsystem is composed of the extensions of major Tug subsystems to the Orbiter as are necessary for performing the major preflight, flight, and post flight operations. These operations are:

- Preflight Ground Testing and Checkout
- Launch Phase Monitoring
- Pre-release Checkout
- Activation of Subsystems
- Deployment of the Tug/Payload
- Monitoring in Orbiter Proximity
- Monitoring during Tug Mission Operation
- Command/Control in Orbiter Proximity
- Subsystem Deactivation
- Retrieval of the Tug/Payload
- Stowage of the Tug/Payload
- Passivation and Safing of Tug/Payload
- Return Flight Monitoring
- Safety Provisions
- Ground Support Interfacing

The Orbiter Tug/interface represents the provisions for mating two major systems -- each of which is capable of independent operation when parted in space. While mated, the Tug is dependent to a degree upon the support capability of the Orbiter and of the ground through the Orbiter. Although passive during most of the launch and landing periods, continuous safety and subsystem status monitoring is sustained by the Orbiter crew.

The Orbiter conducts many missions which do not include the Tug, however, and it is essential that the Tug interfaces produce minimum design and operational impacts upon the Orbiter. In order to minimize these impacts, the Tug ancillary hardware is designed for easy removal and installation. The cabin provisions consist of a dedicated portion of the Mission Specialist Station and multiplexed interfaces with the Orbiter Data Management, computation, and display equipment. This allows accessing and display of Tug subsystem status for monitoring, diagnosis and, through the Tug-unique dedicated panel section, sufficient control to take corrective action.

The interface functions and interface hardware were described in detail in Vol. V, Section 2.4.5 and the design approach, requirements, and characteristics were described in Section 2.5.4.

The principal functions and hardware groups are listed below and are shown in Figure 2.4-1.

The major Shuttle/Tug interface operations and support activities which define the Tug operational support requirements placed upon the Shuttle are shown in Figures 2.4-2 (pre-launch and launch operations), 2.4-3 (on-orbit operations for Tug deployment) and 2.4-4 (on-orbit operations for Tug retrieval). Operational details and timelines are provided in Section 6.5.1, crew activities and functions in Section 5.2, and Shuttle computer support requirements in Section 5.3. The abort operations and the supporting analysis are contained in Section 6 and are summarized in Section 2.5.

FUNCTIONS

- o Operations (listed above and discussed in Section 6.0).
- o Safety (discussed in Volume 7.0).
- o Structural/Mechanical Support (attachments, mountings, manipulation provisions)
- o Fluid/Propulsion Support (fill/drain/vent/purge/abort provisions)
- o Thermal Conditioning Support (temperature control provisions)
- o Avionics Support (electrical/electronics, checkout/monitor/control provisions, with data management, communications, electric power, guidance/navigation/control subsystems)
- o Payload Support (checkout/monitoring, control, caution/warning, safing, electrical power circuits routed through the Tug)

HARDWARE GROUPS

- o Tug Support Structure (tilt table)
- o Tug Support Attachments (hard points, latches, locks, support frame adapters)
- o Remote Manipulating System (RMS arm is part of Orbiter mechanisms, Tug-unique end effector with TV and lighting is charged to Tug support)
- o Fill/Drain/Vent/Purge/Abort Line Assemblies (includes vacuum-jacketed low temperature lines and purging provisions)
- o Fluid Panels and Retraction Mechanisms (purging provisions, locks, actuators, drives, drive controls)
- o Electrical/Electronics Support (instrumentation, sensors, caution and warning circuits, electrical cables/connectors, interface units, junction boxes, test points, inhibit functions/circuits/buses, drive control electronics, TV/lighting)

SHUTTLE/TUG INTERFACES

HARDWARE LOCATIONS

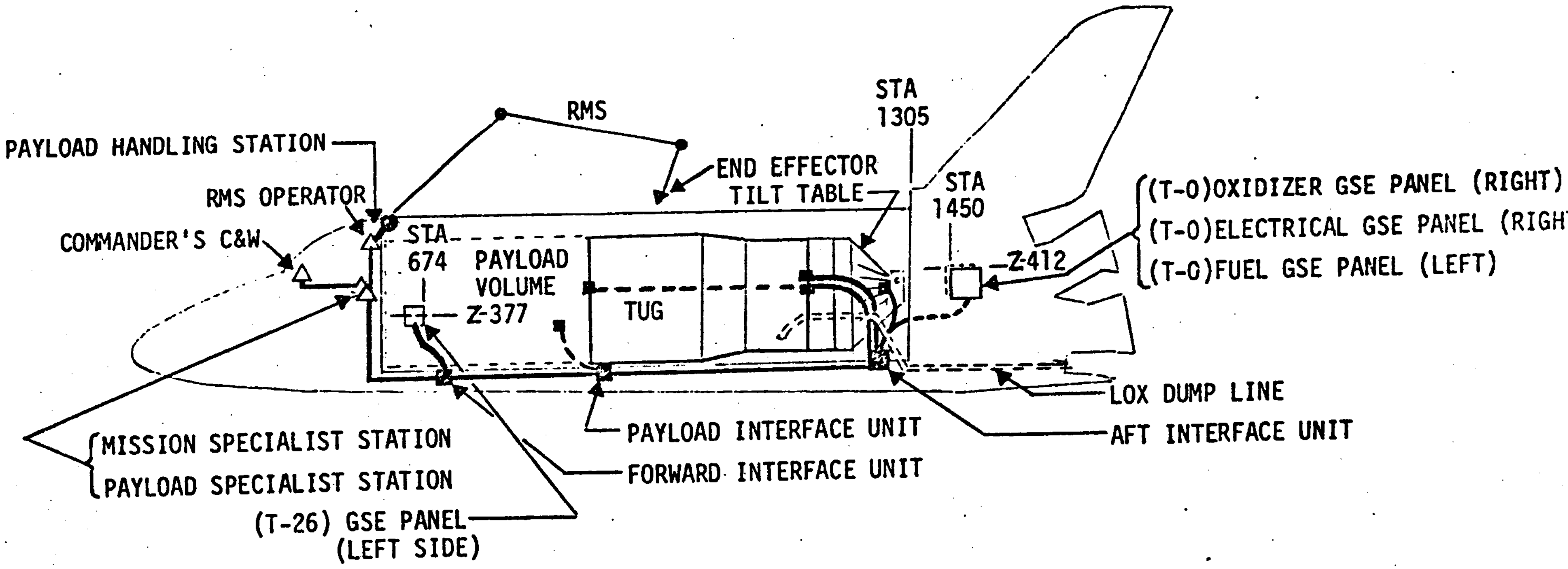
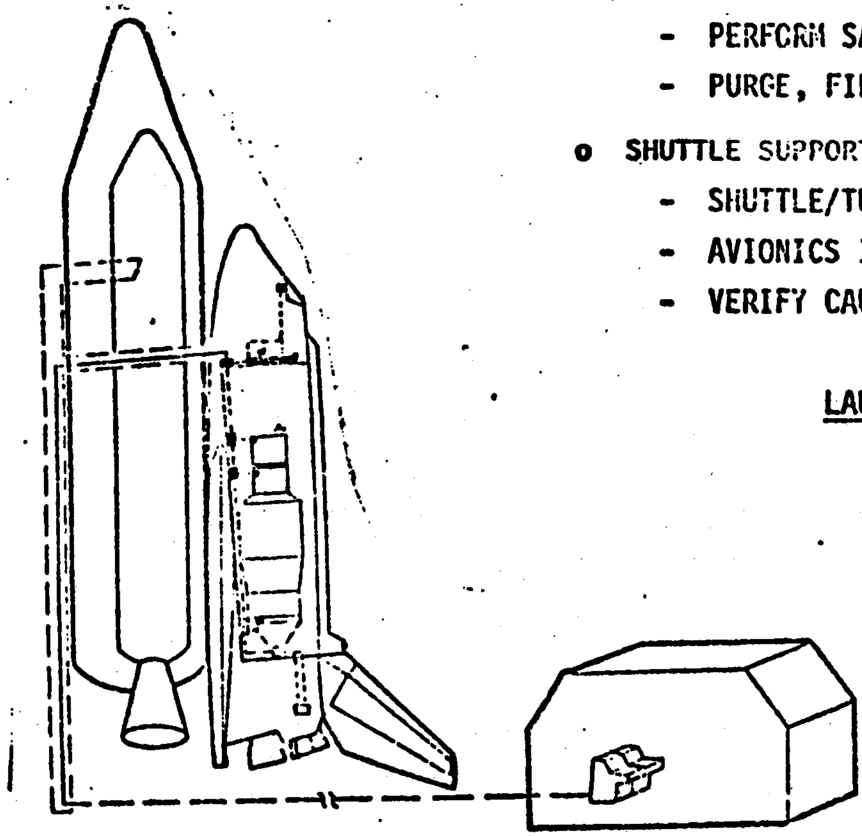


Figure 2.4-1

SHUTTLE / TUG INTERFACES
PRELAUNCH AND LAUNCH OPERATIONS



PRELAUNCH OPERATIONS

- o GROUND SUPPORT
  - MATE AND VERIFY INTERFACES/ATTACHMENTS
  - CHECKOUT TUG SYSTEMS
  - PERFORM SAFETY CHECKOUT
  - PURGE, FILL, DRAIN, VENT TANKS
- o SHUTTLE SUPPORT
  - SHUTTLE/TUG COMPATIBILITY CHECK
  - AVIONICS INTERFACE CHECK
  - VERIFY CAUTION AND WARNING SIGNALS

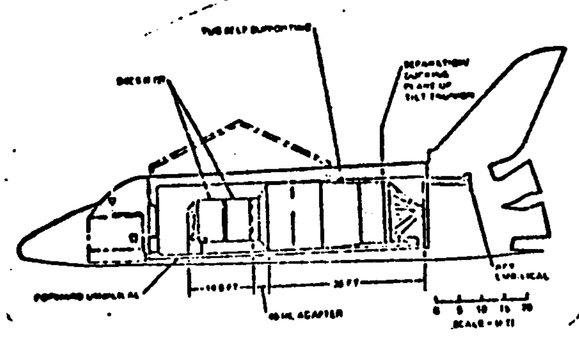
LAUNCH OPERATIONS

- o GROUND SUPPORT
  - PERFORM UMBILICAL RETRACTION
  - SUPPORT COUNTDOWN AND LAUNCH
- o SHUTTLE SUPPORT
  - PROVIDE FLIGHT MONITORING (C/W)
  - SUPPORT TUG SYSTEM MONITORING (PSS/MSS)
  - PROVIDE ELECTRICAL/THERMAL SUPPORT

Figure 2.4-2

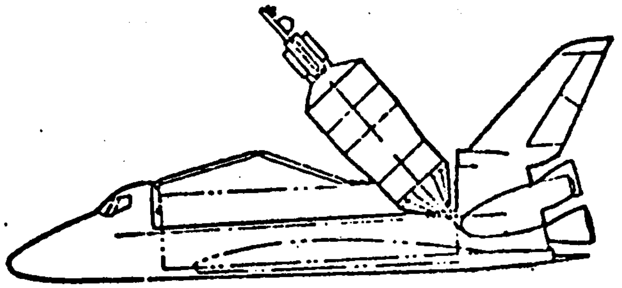
SHUTTLE / TUG INTERFACES

ON-ORBIT OPERATIONS FOR TUG DEPLOYMENT



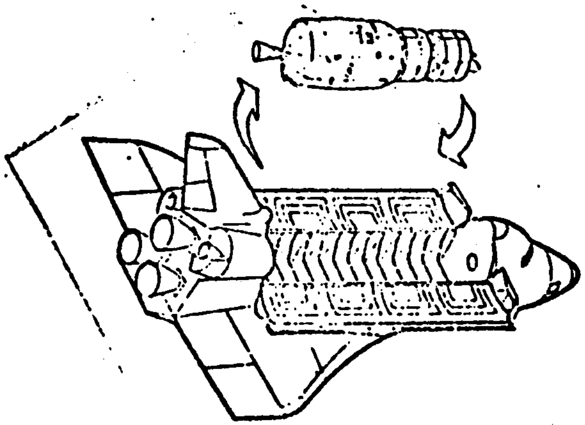
PRE-RELEASE CHECKOUT

- o ELECTRICAL/THERMAL SUPPORT
- o TUG READINESS CHECKS
- o GUIDANCE AND NAVIGATION DATA CHECK/UPDATE/INITIALIZATION



DEPLOYMENT

- o FWD UMBILICAL RETRACTION (FLUID CONNECTIONS)
- o TILT TABLE OPERATION TO 50 DEGREES
- o TUG FUEL CELL POWERPLANT (FCP) STARTUP
- o TUG SYSTEM FULL ACTIVATION AND CHECKOUT
- o AFT UMBILICAL RETRACTION (AVIONICS/ELECTRICAL INTERFACES)
- o REMOTE MANIPULATING SYSTEM (RMS) OPERATIONS (GRASP, LOCK, TRANSLATE, ROTATE, UNLOCK, RELEASE)

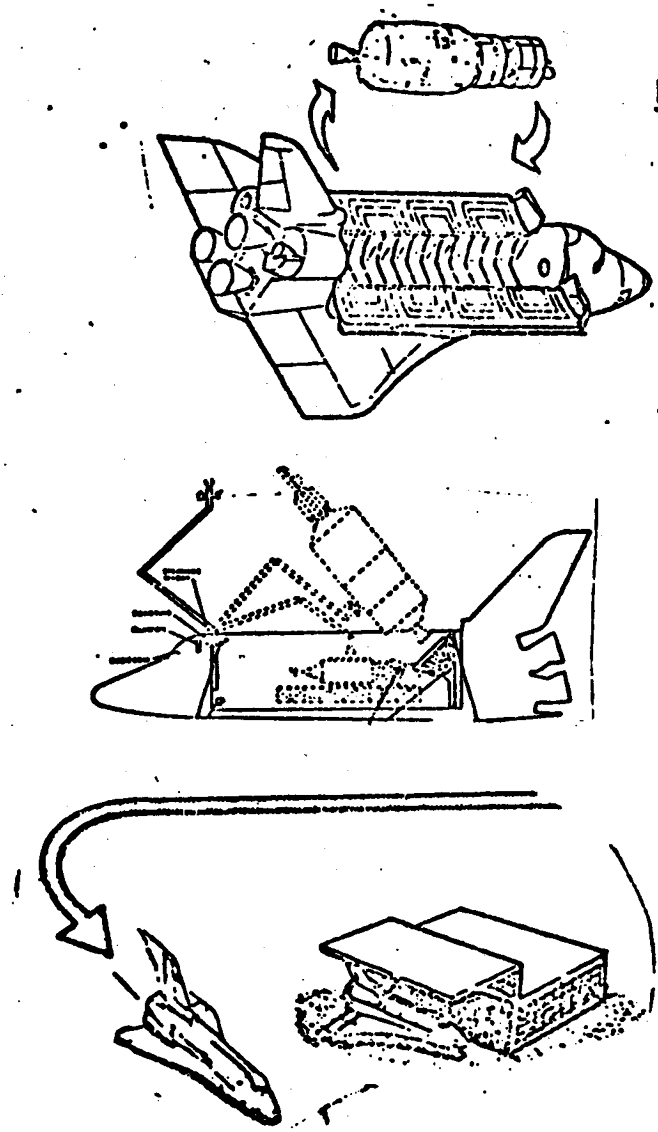


CO-ORBITAL CHECKOUT

- o ACTIVATE ON-BOARD PRESSURE SYSTEMS (i.e., PROPULSION)
- o VERIFY SYSTEM PERFORMANCE/FLIGHT READINESS
- o VERIFY AVIONICS SYSTEM STATUS/PERFORMANCE
- o FINAL UPDATE GUIDANCE/NAVIGATION/CONTROL (GNC) DATA
- o INITIATE TUG FLIGHT AND MONITOR IN ESCORT MODE

Figure 2.4-3

SHUTTLE / TUG INTERFACES
ON-ORBIT OPERATIONS FOR TUG RETRIEVAL



PRE-RETRIEVAL OPERATIONS (SHUTTLE)

- PERFORM RENDEZVOUS MANEUVERS
- MONITOR TUG RENDEZVOUS MANEUVERS TO STAND-OFF POSITION
- COMMAND PARTIAL SYSTEM DEACTIVATION, CRYOGEN DUMP AND HELIUM PURGE OF TUG TANKS
- VERIFY TUG SYSTEM STATUS (PASSIVATION & SAFETY)

RETRIEVAL OPERATIONS (SHUTTLE)

- APPROACH TUG AND PERFORM STATIC DISCHARGE
- RETRIEVAL OF TUG (PAYLOAD) WITH RMS
- STOWAGE OF TUG (PAYLOAD) IN PAYLOAD BAY
- RECONNECT MINIMUM UMBILICALS (AVIONICS/ELECTRICAL, FLUID-TBD)
- VERIFY TUG (PAYLOAD) SAFETY AND SYSTEM DEACTIVATION

RETURN AND LANDING OPERATIONS (SHUTTLE)

- PROVIDE RETURN FLIGHT MONITORING (C/W)
- PROVIDE DYNAMIC PROFILE MONITORING
- PROVIDE ELECTRICAL SUPPORT FOR TUG (PAYLOAD)

POST-LANDING OPERATIONS (GSE)

- THERMAL CONDITIONING OF TUG AND PAYLOAD BAY (COOL-DOWN)
- SYSTEM PASSIVATION AND SAFETY VERIFICATION
- EQUIPMENT/SYSTEM TESTING AND REFURBISHMENT

Figure 2.4-4

2.5 Abort Analysis Summary

The abort analysis is derived from an assessment of the requirements, constraints and design limitations. The selected abort provisions were described in Volume 5, Section 2.4.5.4 for both suborbital Mode III and Orbital Mode IV, V, or VI aborts. The options considered are discussed in the trade study reported in Section 12.6. The selected options for cryogen handling for both normal and aborted missions are shown in Table 2.5-1.

The timelines are provided for each of the selected abort options in Section 6.1; the shuttle requirements to support these timelines are given in Section 6.2; an altitude versus time analysis is provided in Section 6.3, and analyses of the Delta-V implications of propulsive abort dumping and of the effects of reduced weight during main engine operation are given in Section 6.4

The conclusions reached and a summary of the abort analysis are provided by Tables 2.5-2 and 2.5-3.

Table 2.5-1

CRYOGEN HANDLING

CONDITION	LO_2	LH_2
Normal Mission		
Passivation: (Before Tug capture)	o Keep residual LO_2 o Vent above 18 psia	o Flow residual LH_2 through engine down to 3 psia
Venting: (After Tug capture/ stowage)	o Keep residual LO_2 o Vent above 18 psia	o Vent again to 3 psia o Fill with ambient He to 26.3 psia o Vent down to 16±1 psia o Vent above 18 psia
Aborted Mission		
Suborbital: (Mode III)	Dump LO_2 to 15 psia: (1) During engine firing, 20% minimum through 3" abort line (2) After ET jettison, remainder through 3-inch abort line	Nominal o Keep LH_2 in tank o Vent above 18 psia Alternative Study Options o Dump sequentially after LO_2 (CG constraint) down to 110K ft through two 5 inch abort lines o Dump simult. thru 3-In.line
Orbital: (Mode IV,V,VI)	Dump LO_2 to 15 psia: Primary Method: (1) During orbital flight, 100% through 2-inch F/D port and tap to 3-inch abort line. Alternative (Backup) Method: (1) During orbital flight, ~40% through 3-inch abort line (2) During reentry glide, remainder through 3-inch abort line	Preferred-Options 2 & 3F o Dump under vapor pressure to 15 psia o Keep remainder o Vent above 18 psia Preferred-Options 1 & 3I o Dump under vapor pressure to 3 psia o Fill with ambient He to 26.3 psia o Vent down to 16±1 psia o Vent above 18 psia Alternative (Backup) o Keep LH_2 in tank o Vent above 18 psia

Table 2.5-2

ABORT MODE ANALYSIS SUMMARY AND CONCLUSIONS

Mode I - No dump; continue flight to Modes II or III abort period.

Mode II - No dump; SRB thrust termination eliminated, SRB separation at 115 sec before dumping is permitted (No Mode II abort, as directed by COR instructions).

Mode III - Start LOX dump at T+116 to T+251 sec; 310 to 280 sec are available before MECO-30, 704 to 649 sec after MECO+30.

o Adequate time is available from a 3-inch LOX dump line for Mode III abort.

o Cryogen dump during engine operation is acceptable according to NASA study directives.

o Dump LOX and/or LH_2 when liquid/gas interface is relatively stabilized.

o Simultaneous dumping is reported to be acceptable when all the following conditions prevail:

- LOX and LH_2 outlets are separated by $\geq$ 300 inches
- Atmospheric pressure $\geq$ 0.1 psia
- Altitude is $\geq$ 110,000 ft

o Sufficient time exists above 110,000 ft in a Mode III abort for simultaneous LH_2 dump with a 3-inch line, including dump time before and after MECO.

o Sufficient time exists above 110,000 ft in a Mode III abort for sequential LH_2 dump with a 4-inch line, including dump time before and after MECO.

o Insufficient time exists above 110,000 ft in a Mode III abort for LH_2 dump in stable condition, after MECO.

o Sufficient time exists above 110,000 ft in a Mode III abort for LH_2 dump in variable condition with a 5-inch line, after MECO.

o Land full will cause an undesirable reduction of payload capability (-2,051 lb)

CONCLUSIONS:

(1) LO_2 dump is recommended for suborbital abort.

(2) LO_2 and LH_2 dump is recommended for orbital abort.

Table 2.5-3

ABORT STUDY ASSESSMENT

	LAND FULL	DUMP CRYOGENS		
		LO_2 ONLY	LO_2 AND LH_2	
		3 IN. LINE	SEQUENTIAL 3.5 IN. & 5 IN.	SIMULTANEOUS 3 IN. & 5 IN.
Δ TUG WEIGHT (LB)	+806	+144	+177	+164
Δ ORBITER WEIGHT (LB)*	+94	+340	+1303	+1297
Δ PAYLOAD WEIGHT (LB)				
ROUND TRIP**	-815	-178	-307	-294
GEOSYNCH DEPLOY***	-2015	-489	-938	-903

LAUNCH FULL, LAND FULL

- SAFETY ASPECTS QUESTIONABLE
- CANNOT ACCOMMODATE CRASH LOAD FACTORS (ABORT AND CRASH LANDING ARE NOT CONCURRENT CONDITIONS FOR THIS STUDY)
- LANDING CG OUTSIDE OF JSC 07700 PROFILE RANGE

DUMP SYSTEMS

- SUBORBITAL DUMP IN MODE III ABORT (T +116 SEC OR LATER)
- SIMULTANEOUS LH_2 DUMP AND LO_2 DUMP DEPENDS ON TIME AVAILABLE ABOVE 110K FT
- SEQUENTIAL DUMP IS PREFERRED WHEN TIME AVAILABLE, FOR SAFETY MARGIN
- SIMULTANEOUS DUMP SAFETY DEPENDS ON ATMOSPHERE PRESSURE AND OUTLET PORT SEPARATION
- PAYLOAD WEIGHT IMPACT & CG BENEFIT CONTRIBUTE TO LO_2 DUMP PREFERENCE

RECOMMENDATION: LO_2 DUMP

* INCLUDES ANCILLARY EQUIPMENT

** $\Delta W_{PL} = -[\Delta W_{TUG} + 0.1 (\Delta W_{ORBITER})]$ FOR ROUND TRIP

*** $\Delta W_{PL} = -[\Delta W_{TUG} \times 2.5 + 0.38 (\Delta W_{ORBITER})]$ FOR DEPLOY TO GEOSYNCH ORBIT

2.6 Operational Complexity

Option 3 includes two Tug configurations, an initial and a final. The initial configuration has low performance capability and no retrieval. Lack of rendezvous, docking, and spin-up capability and short mission duration contribute to a low level of complexity. The number of critical events is low due to limited mission capabilities and duration which also results in low complexity. The low autonomy level (IV) increases complexity but the overall level is considered low.

The final configuration has high performance capability, rendezvous, docking and spin-up capability, longer (six-day) mission duration and a resulting high number of critical events. All of these factors incur high complexity levels as does the low autonomy level (III). The overall complexity level is considered to be high.

2.7 KICK STAGE DATA SUMMARY

The use of a kick stage on four of the NASA planetary missions (19, 20, 21 and 23), with both initial and final Tugs, and one DOD mission (11a), with the initial configuration, allows these missions to be flown in a reusable mode with the Tug. These were the only missions where the use of a kick stage was required.

A range of acceptable kick stage sizes was established parametrically for the NASA missions. A survey of existing solid rocket motors was made in an attempt to identify an existing stage which could be utilized for the Tug missions. Several constraints, such as stage length and thrust to weight were used in making the final selection. The stage most nearly meeting the requirements was the second stage of the Polaris A3. This stage is considerably oversized for the DOD mission but can be flown in an off optimum manner. The use of a smaller kick stage was not considered cost effective.

Design details of this stage are classified and may be found in the confidential document Rocket Motors Manual (U), Unit 411, Chemical Propulsion Information Agency, John Hopkins University.

In an attempt to minimize changes to a standard tug/payload interface, the tug/payload/kick stage interface shown in Figure 2.7-1 was conceived. By replacing the standard tug/payload interface truss with the one shown, the tug/payload interface remains the same, with the exception that the interface plane moves forward. The longer struts allow the kick stage to interface directly with the payload interface ring. There is no direct structural interface between the tug and kick stage. The longer struts were designed by the combined payload kick stage loads. Electrical interface between tug and kickstage is accommodated through the tug/payload electrical interface panel. In essence, the kick stage appears as part of the payload to the tug.

Operationally, the Tug separates from the payload/kick stage combination in the same manner as separating from a payload. The Tug provides the proper flight path angle prior to separation. After an appropriate separation distance is established, the kick stage is fired completing the payload velocity requirement. The kick stage must provide thrust vector control during its burn. The tug is then free to return to the shuttle.

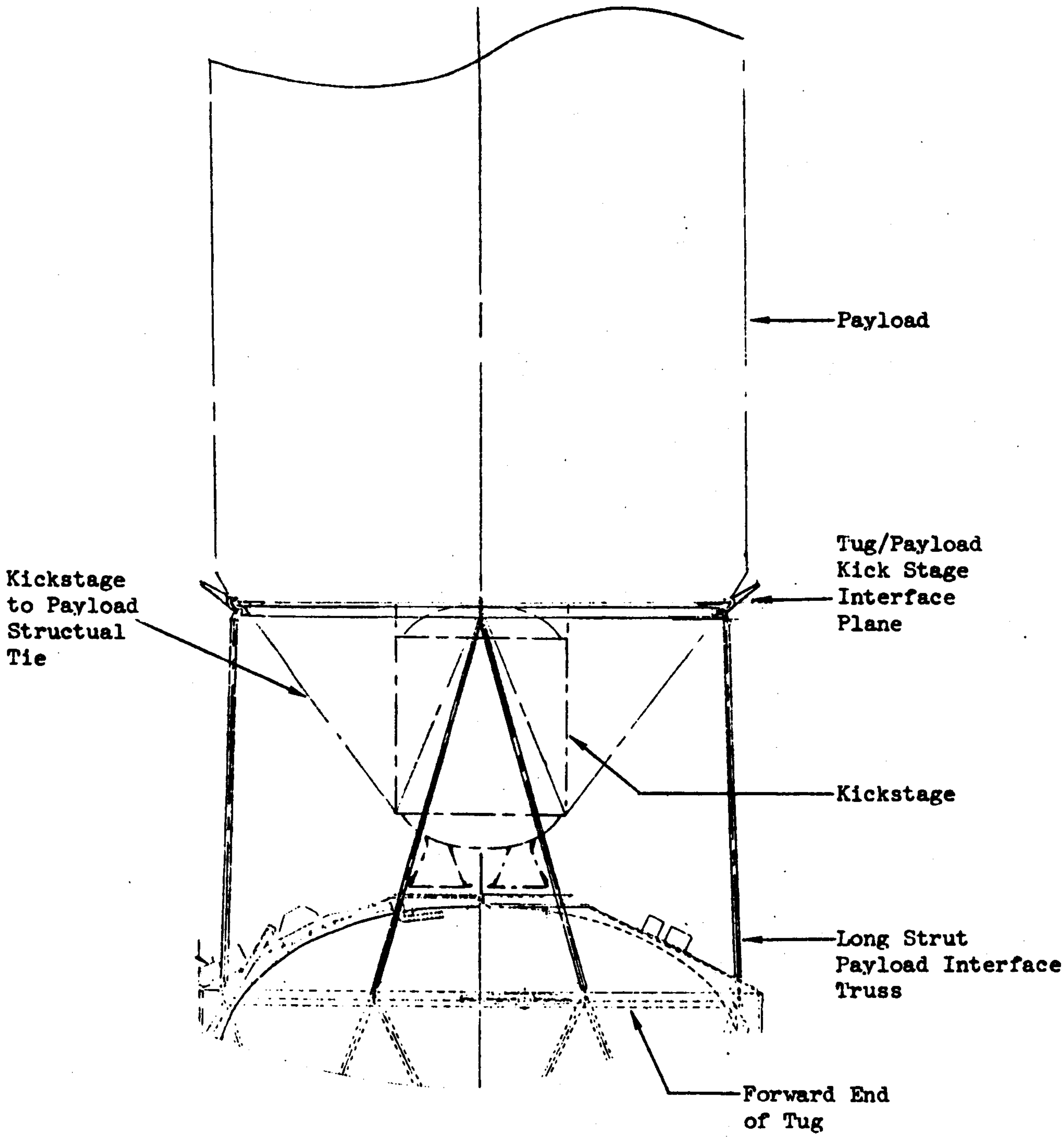


Figure 2.7-1. TUG/PAYLOAD - KICKSTAGE INTERFACE

3.0 ORBITAL OPERATIONS PERFORMANCE DATA (SOFT Panel Format)

The parametric performance capabilities (payload vs. velocity curves) for three inclinations, 28.5 deg, 55 deg and 90 deg, were determined for each configuration. Option 3I and 3F data are shown in Figure 3-1 through -6 with the other options following in sequence. Additional details of the assumptions and applications pertaining to these data are given in Volume IV, Sections 1.1, 1.3, and 1.4.

PERFORMANCE CAPABILITY

CONFIGURATION 3T

W_{BO} 7315

I_{SP} 441.8

INCL 28.5°

① DEPLOY

② RETRIEVE

③ ROUND TRIP

④ EXPENDABLE

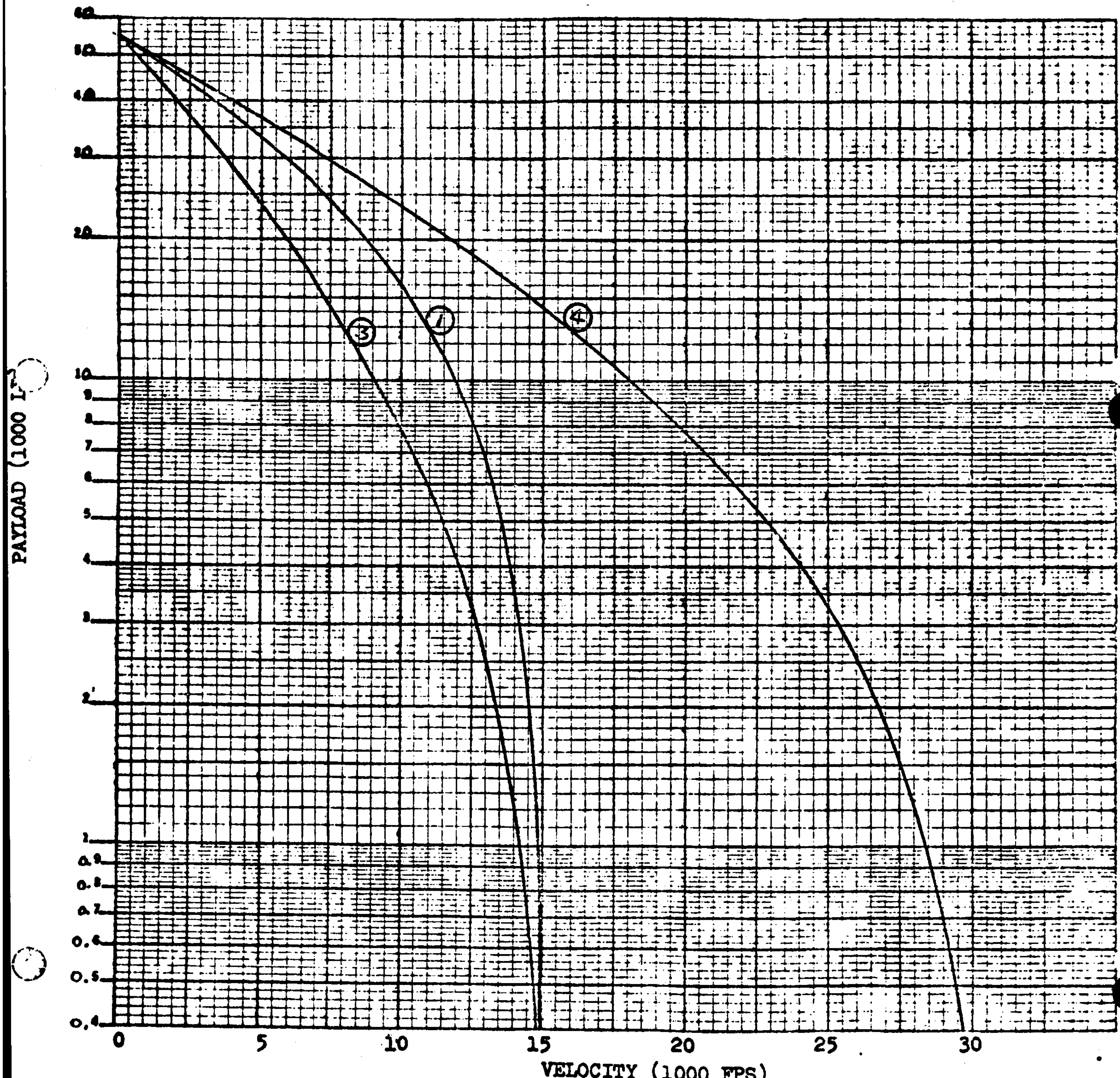


Figure 3-1

PERFORMANCE CAPABILITY

CONFIGURATION 3I

W_{BO} 7315

I_{SP} 441.8

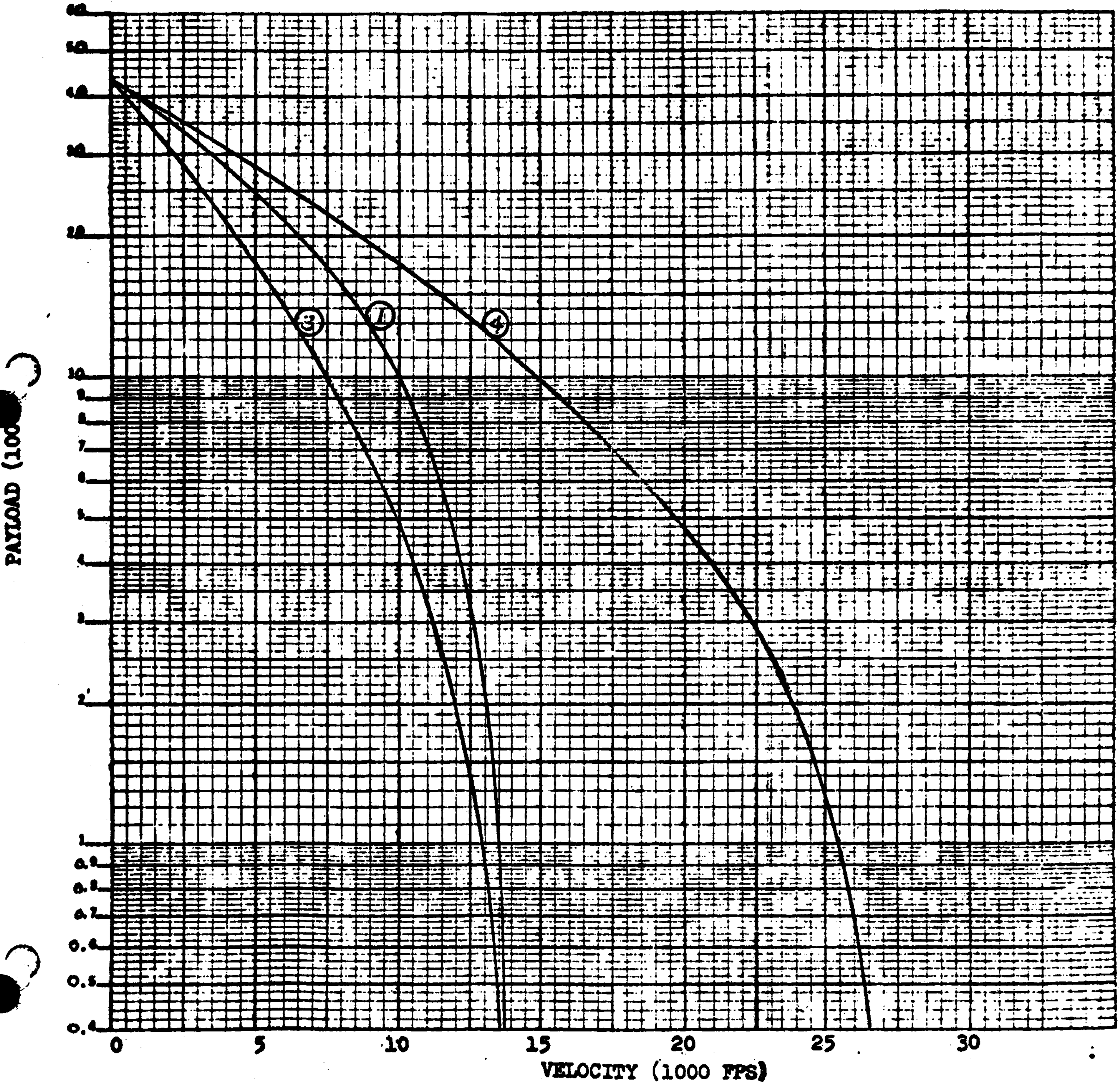
INCL 55°

① DEPLOY

② RETRIEVE

③ ROUND TRIP

④ EXPENDABLE



3-3 Figure 3-2

PERFORMANCE CAPABILITY

CONFIGURATION 3I

W_{BO} 7315

I_{SP} 441.8

INCL 90°

① DEPLOY

② RETRIEVE

③ ROUND TRIP

④ EXPENDABLE

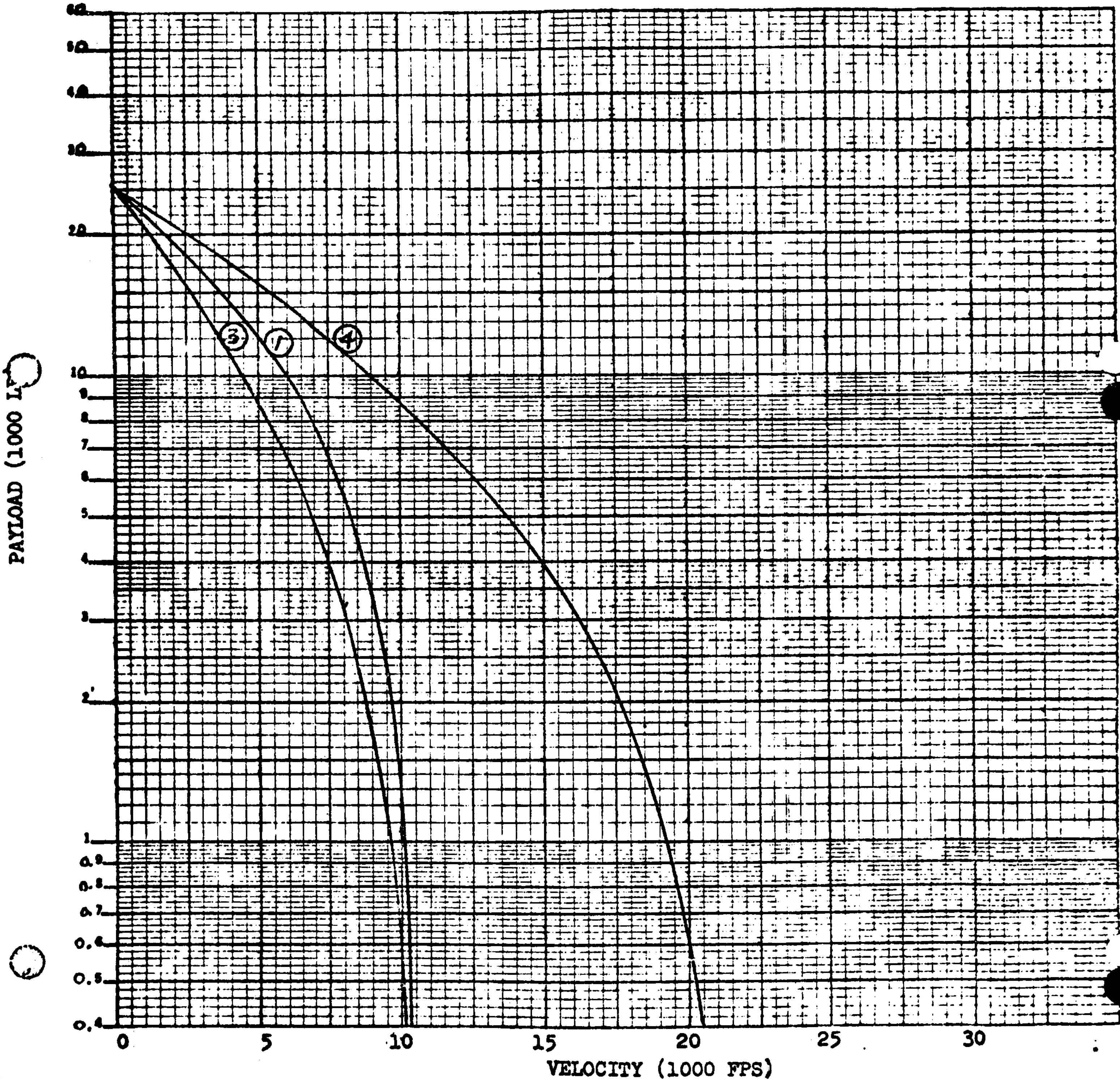


Figure 3-3

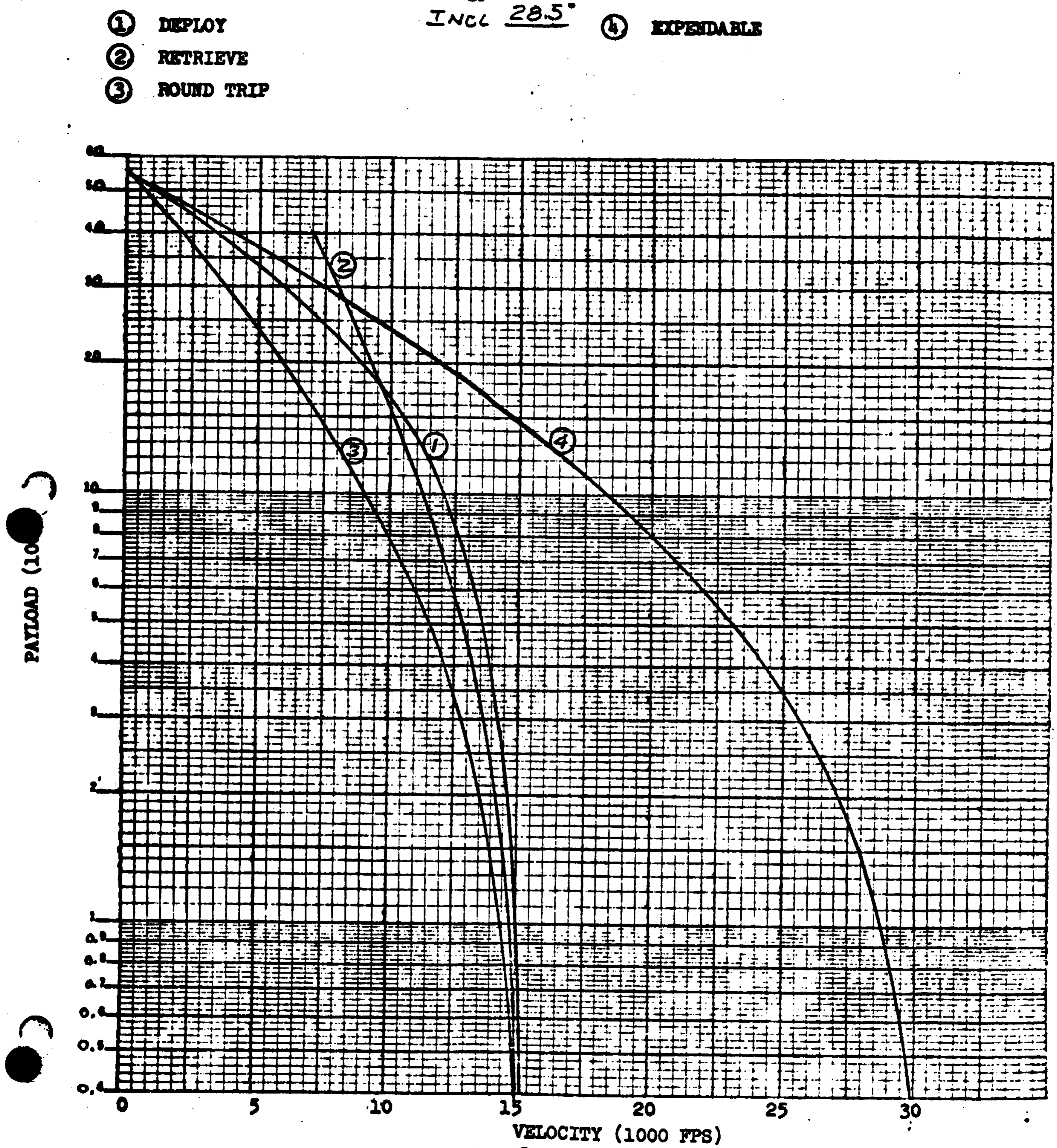
PERFORMANCE CAPABILITY

CONFIGURATION 3F

W_{BO} 7039

I_{SP} 441.8

INCL 28.5°



3-5

Figure 3-4

PERFORMANCE CAPABILITY

CONFIGURATION 3F

W_{BO} 7039

I_{SP} 441.8

INCL 55°

① DEPLOY

② RETRIEVE

③ ROUND TRIP

④ EXPENDABLE

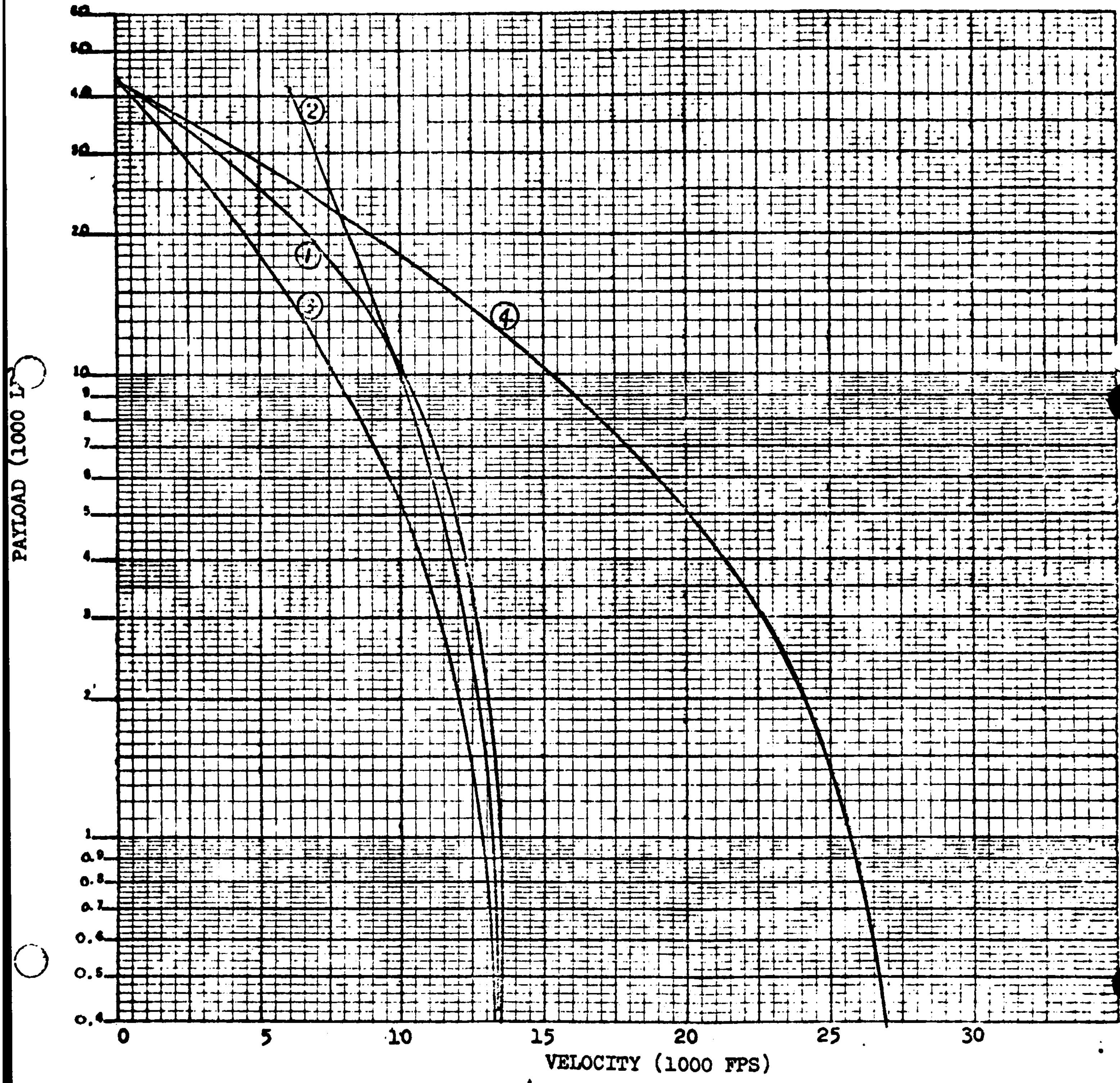


Figure 3-5

PERFORMANCE CAPABILITY

CONFIGURATION 3F

W_{BO} 7039

I_{SP} 441.8

INCL 90°

① DEPLOY

② RETRIEVE

③ ROUND TRIP

④ EXPENDABLE

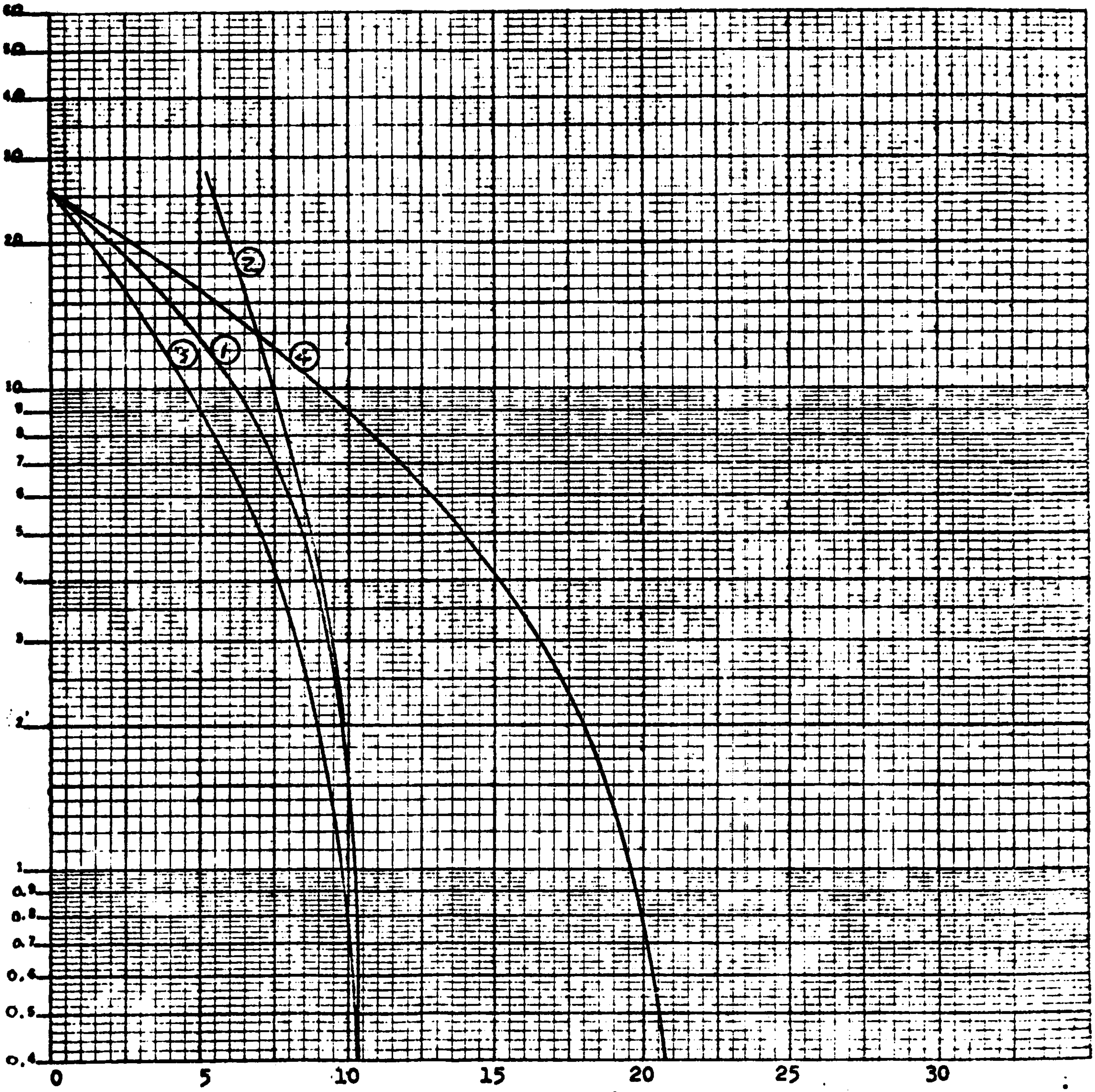
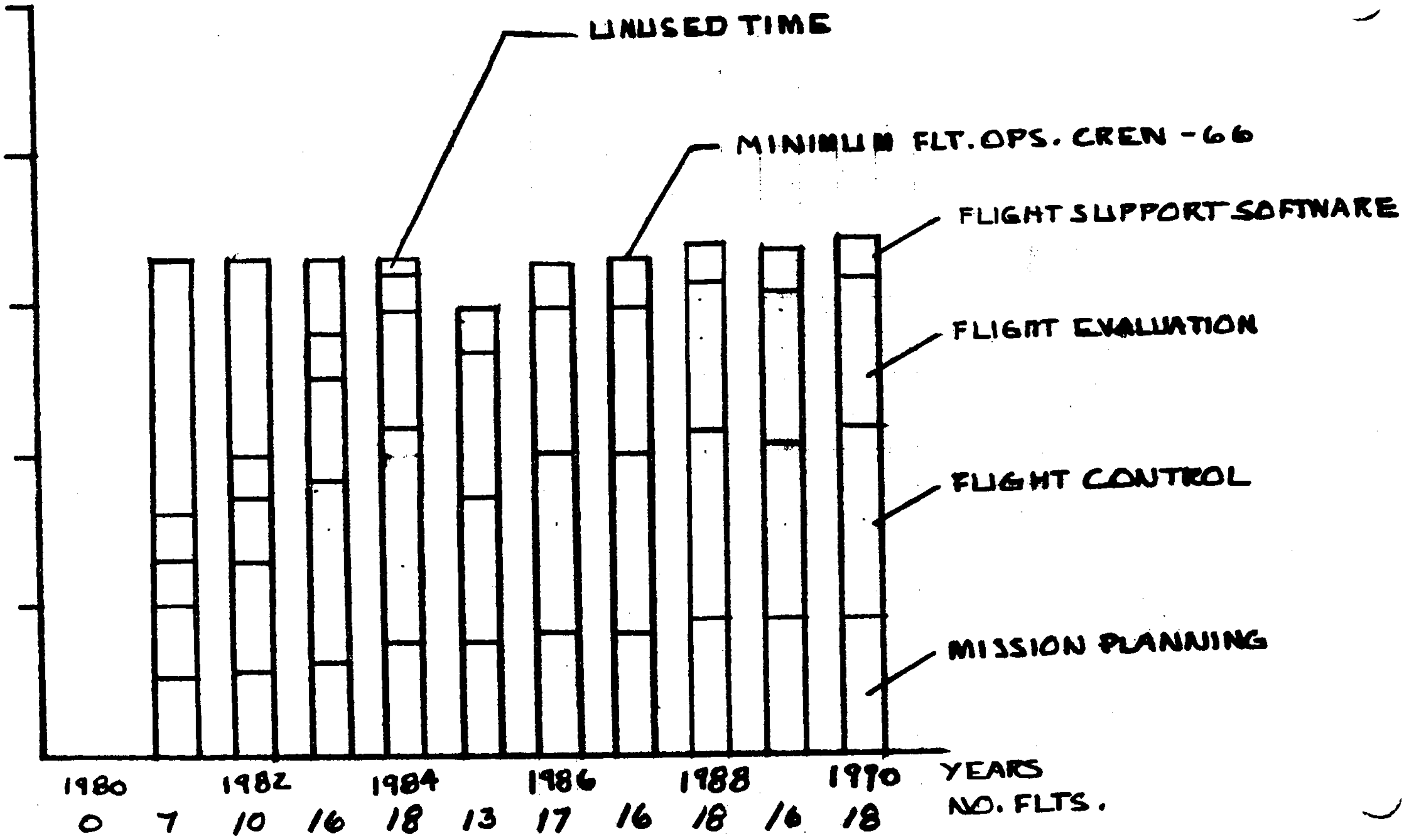


Figure 3-6

4.0 Orbital Operations Costs

The flight operational functions are described in the following Flight Operations description sheets, Sections 4.1 through 4.9. Costs are presented in terms of ground support manpower and computer hours in these sheets.

These data as shown in Fig. 4-1 and 4-2 are summarized in this section and are converted to dollars.

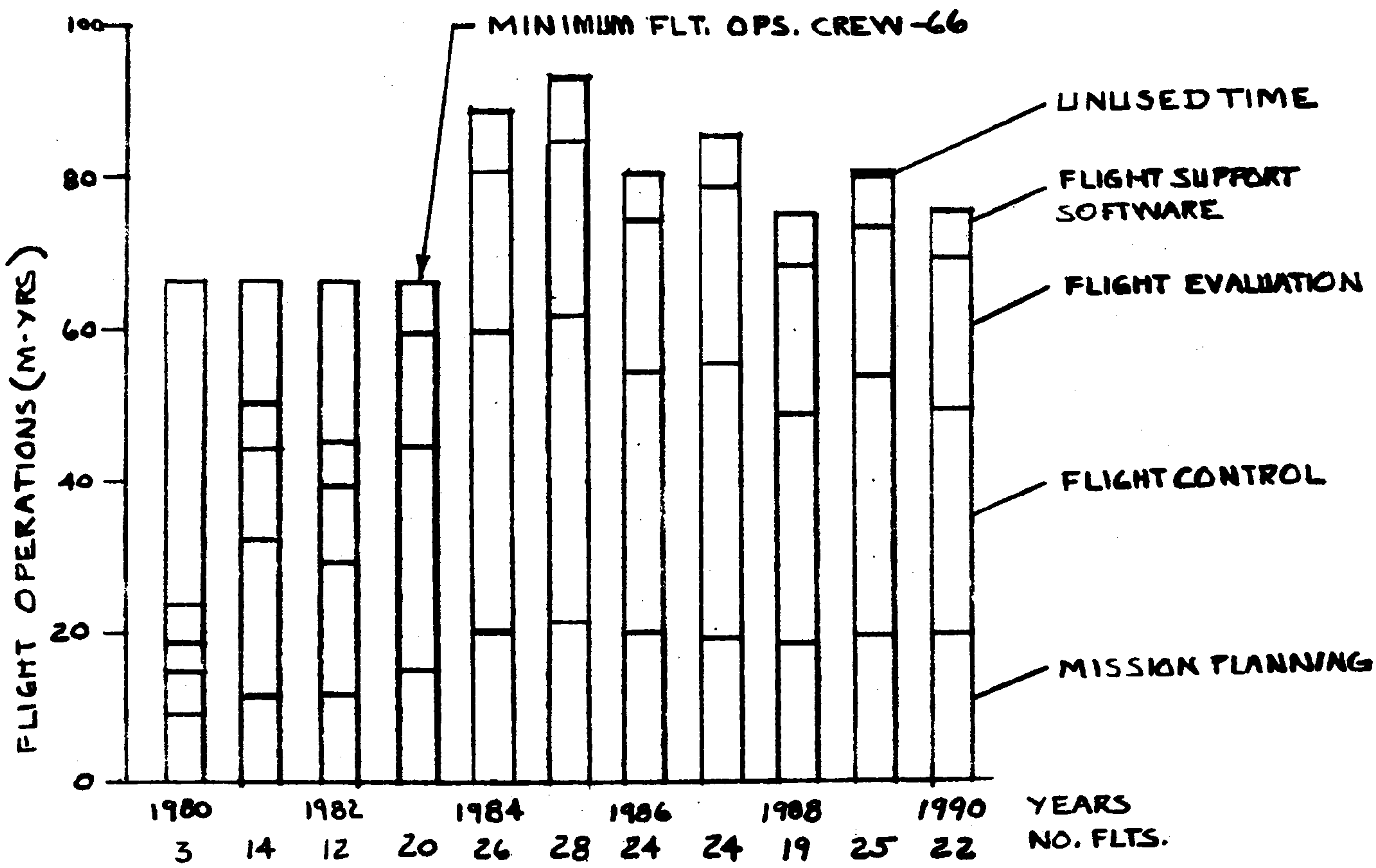


OPTION 3 (DOD MISSION)

TOTAL MANYEARS	=	656
MISSION PLANNING	=	153
FLIGHT CONTROL	=	216
FLIGHT EVALUATION	=	157
FLIGHT SUPPORT SOFTWARE	=	60
UNUSED TIME	=	70

TOTAL FLIGHTS	=	149
WTR FLIGHTS	=	21
ETR FLIGHTS	=	128

FIGURE 4-1 FLIGHT OPS. MANPOWER REQUIRED



OPTION 3 (NASA MISSION)

TOTAL MANYEARS	= 843
MISSION PLANNING	= 186
FLIGHT CONTROL	= 313
FLIGHT EVALUATION	= 187
FLIGHT SUPPORT SOFTWARE	= 77
UNUSED TIME	= 80

TOTAL FLIGHTS	= 217
WTR FLIGHTS	= 37
ETR FLIGHTS	= 180

FIGURE 4-2 FLIGHT OPS. MANPOWER REQUIRED

OPTION = 3

YEAR = 198[illegible]

NUMBER OF FLIGHTS = 3.0

AUTONOMY LEVEL = 1.0

NASA MISSION

MISSION DURATION = 43.0

LAUNCH FROM WTR = 0.0

LAUNCH FROM ETR = 3.0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

	MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING =	17615.[illegible]	15[illegible].6	4[illegible]9990.4
FLIGHT CONTROL =	1[illegible]1256.3	221.3	2123870.4
FLIGHT EVALUATION =	5220.5	63.8	1[illegible]919.7
FLIGHT SOFTWARE =	12[illegible]	43.3	33[illegible]753.4
UNUSED MANHOURS =	92453.0	0.0	1849059.2
TOTAL OPS. HOURS =	124[illegible]	439.6	
TOTAL OPS. COSTS =	23[illegible]	187533.9	2995533.9

OPERATIONS PER/FLT COSTS = 99[illegible]511.3

OPTION = 3

YEAR = 1981

NUMBER OF FLIGHTS = 14,0

AUTONOMY LEVEL = 4,0

NASA MISSION

MISSION DURATION = 41,1

LAUNCH FROM WTR = 0,0

LAUNCH FROM ETR = 14,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	26[illegible]15,2	235,0	611466,7
FLIGHT CONTROL	=	74713,4	1007,4	18[illegible]0210,4
FLIGHT EVALUATION	=	24[illegible]66,4	316,7	6[illegible]2609,7
FLIGHT SOFTWARE	=	1248[illegible]	173,6	378476,3
UNUSED MANHOURS	=	31[illegible]20,3	0,0	624406,7
TOTAL OPS, HOURS	=	124[illegible]	1735,7	
TOTAL OPS, COSTS	=	28[illegible]	664763,1	3472763,1

OPERATIONS PER/FLT COSTS = 24[illegible]054,5

4-5

OPTION = 3

YEAR = 19[illegible]

NUMBER OF FLIGHTS = 12,0

AUTONOMY LEVEL = 4,0

NASA MISSION

MISSION DURATION = 40,5

LAUNCH FROM WTR = 0,0

LAUNCH FROM ETR = 12,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	24452,3	221,8	573980,6
FLIGHT CONTROL	=	798[illegible]9,6	856,7	1924308,2
FLIGHT EVALUATION	=	2[illegible]38,1	27[illegible],2	514262,8
FLIGHT SOFTWARE	=	1240[illegible]	14[illegible],9	369394,6
UNUSED MANHOURS	=	42755,9	0,0	855118,3
TOTAL OPS. HOURS	=	124[illegible]	149[illegible],6	
TOTAL OPS. COSTS	=	28[illegible]	57394[illegible],2	33[illegible]946,2

OPERATIONS PER/FLT COSTS = 281828,9

OPTION = 3

YEAR = 1983

NUMBER OF FLIGHTS = 20,0

AUTONOMY LEVEL = 4,0

NASA MISSION

MISSION DURATION = 38,4

LAUNCH FROM WTR = 4,0

LAUNCH FROM ETR = 16,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	36377,[illegible]	283,4	716085,8
FLIGHT CONTROL	=	6[illegible]719,[illegible]	138[illegible],1	1746044,7
FLIGHT EVALUATION	=	337[illegible]3,7	443,5	843922,1
FLIGHT SOFTWARE	=	1248[illegible],[illegible]	235,0	4[illegible]2005,8
UNUSED MANHOURS	=	3[illegible]6,9	0,0	6138,4
TOTAL OPS, HOURS	=	124[illegible],[illegible]	2350,0	
TOTAL OPS, COSTS	=	2308[illegible],[illegible]	900053,5	37[illegible]8053,5

OPERATIONS PER/FLT COSTS = [illegible]87402,9

OPTION = 3

YEAR = 1984

NUMBER OF FLIGHTS = 26,0

AUTONOMY LEVEL = 3,0

NASA MISSION

MISSION DURATION = 39,0

LAUNCH FROM WTR = 4,0

LAUNCH FROM ETR = 22,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	42554,3	323,2	994307,0
FLIGHT CONTROL	=	79321,6	1514,8	2166618,0
FLIGHT EVALUATION	=	44121,4	579,1	1102221,0
FLIGHT SOFTWARE	=	16589,7	274,1	519732,2
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS, HOURS	=	165097,8	2741,2	
TOTAL OPS, COSTS	=	3732693,7	1049884,4	4782578,1

OPERATIONS PER/FLT COSTS = 183945,3

OPTION = 3

YEAR = 1985

NUMBER OF FLIGHTS = 28,0

AUTONOMY LEVEL = 3,0

NASA MISSION

MISSION DURATION = 39,0

LAUNCH FROM WTR = 6,0

LAUNCH FROM ETR = 22,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	44552,4	392,7	1043585,0
FLIGHT CONTROL	=	84754,9	1612,0	2312485,4
FLIGHT EVALUATION	=	47231,7	623,6	1179484,1
FLIGHT SOFTWARE	=	17641,4	292,0	552963,2
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS. HOURS	=	176445,0	2920,3	
TOTAL OPS. COSTS	=	[illegible]	1118483,3	5088517,7

OPERATIONS PER/FLT COSTS = [illegible]732,8

OPTION = 3

YEAR = 1986

NUMBER OF FLIGHTS = 24,0

AUTONOMY LEVEL = 3,0

NASA MISSION

MISSION DURATION = 36,7

LAUNCH FROM WTR = 4,0

LAUNCH FROM ETR = 20,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	39386,7	343,1	931056,6
FLIGHT CONTROL	=	71649,3	1373,6	1957929,7
FLIGHT EVALUATION	=	42161,7	525,4	1044475,6
FLIGHT SOFTWARE	=	15369,8	249,3	479745,1
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS, HOURS	=	153697,7	2493,5	
TOTAL OPS, COSTS	=	[illegible]	955003,2	4413206,9

OPERATIONS PER/FLT COSTS = 183883,6

OPTION = 3

YEAR = 1987

NUMBER OF FLIGHTS = 24,0

AUTONOMY LEVEL = 3,0

NASA MISSION

MISSION DURATION = 45,8

LAUNCH FROM WTR = 6,0

LAUNCH FROM ETR = 18,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	41182,1	357,3	960561,5
FLIGHT CONTROL	=	76[illegible],2	1492,6	2091784,8
FLIGHT EVALUATION	=	45[illegible]52,2	561,5	1116080,5
FLIGHT SOFTWARE	=	16224,[illegible]	267,3	508225,3
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS. HOURS	=	1[illegible]274[illegible],8	2679,5	
TOTAL OPS. COSTS	=	3650411,1	1026241,1	4676652,1

OPERATIONS PER/FLT COSTS = 194860,5

OPTION = 3

YEAR = 1980

NUMBER OF FLIGHTS = 19.0

AUTONOMY LEVEL = 3.0

NASA MISSION

MISSION DURATION = 48.6

LAUNCH FROM WTR = 4.0

LAUNCH FROM ETR = 15.0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	37298,7	324,7	882821,1
FLIGHT CONTROL	=	59842,7	1147,9	1636653,0
FLIGHT EVALUATION	=	42917,5	453,3	1031947,8
FLIGHT SOFTWARE	=	14674,6	213,5	433704,0
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS, HOURS	=	149765,8	2135,5	
TOTAL OPS, COSTS	=	3147232,8	817895,1	3985125,9

OPERATIONS PER/FLT COSTS = 209743,5

OPTION = 3

YEAR = 1969

NUMBER OF FLIGHTS = 25.0

AUTONOMY LEVEL = 3.0

NASA MISSION

MISSION DURATION = 35.4

LAUNCH FROM WTR = 5.0

LAUNCH FROM ETR = 20.0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	41679.8	354.8	957440.5
FLIGHT CONTROL	=	70412.7	1328.2	1916958.8
FLIGHT EVALUATION	=	42298.4	542.0	1053541.5
FLIGHT SOFTWARE	=	15378.9	247.2	479157.1
UNUSED MANHOURS	=	0.0	0.0	0.0
TOTAL OPS. HOURS	=	153769.2	2472.2	
TOTAL OPS. COSTS	=	3440256.6	946841.9	4407097.9

OPERATIONS PER/FLT COSTS = 176283.9

OPTION = 3

YEAR = 1990

NUMBER OF FLIGHTS = 22,0

AUTONOMY LEVEL = 3,0

NASA MISSION

MISSION DURATION = 37,5

LAUNCH FROM WTR = 4,0

LAUNCH FROM ETR = 18,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	41463,2	343,1	963101,3
FLIGHT CONTROL	=	59844,3	1060,7	1603115,0
FLIGHT EVALUATION	=	41299,6	484,6	1011563,5
FLIGHT SOFTWARE	=	14263,1	215,4	437150,9
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS. HOURS	=	142531,2	2103,7	
TOTAL OPS. COSTS	=	32[illegible]92 2,4	805728,3	4014930,7

OPERATIONS PER/FLT COSTS = 182496,8

OPTION = 3

TOTAL PROGRAM COSTS

NUMBER OF FLIGHTS =217,0

AUTONOMY LEVEL = 3,0

NASA MISSION

LAUNCH FROM WTR = 37,0

LAUNCH FROM ETR =180,0

FLIGHT OPERATIONS RECURRING COSTS (NASA ONLY)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	3873?7,?	3388,9	9044096,4
FLIGHT CONTROL	=	819?41,0	13000,4	21359978,5
FLIGHT EVALUATION	=	308313,0	4869,5	9631028,2
FLIGHT SOFTWARE	=	159466,0	2362,0	4891308,0
UNUSED MANHOURS	=	146736,1	0,0	3334722,7
TOTAL OPS, HOURS	=	1594667,7	23619,8	
TOTAL OPS, COSTS	=	358?0?22,2	9046388,9	44926411,1

OPERATIONS PER/FLT COSTS = 2?7034,2

FLIGHT OPERATIONS NON-RECURRING COSTS (TOTAL PROGRAM FOR BOTH DOD & NASA)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	478?64,6	2008,0	11543527,2
FLIGHT CONTROL	=	52263.9	0,0	1175938.2
FLIGHT EVALUATION	=	0,0	0,0	0,0
FLIGHT SOFTWARE	=	178005.2	3122.3	5200963.6
TOTAL DDT E HOURS	=	709133.7	5130.3	
TOTAL DDT E COSTS	=	15955509.0	1964904.9	17920429.0

OPTION = 3

YEAR = 1961

NUMBER OF FLIGHTS = 7.0

AUTONOMY LEVEL = 4.0

DOD MISSION

MISSION DURATION = 39.6

LAUNCH FROM WTR = 0.0

LAUNCH FROM ETR = 7.0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	[illegible]	181.8	461789.6
FLIGHT CONTROL	=	92282.[illegible]	493.8	2034916.9
FLIGHT EVALUATION	=	11[illegible].6	156.6	29[illegible].2
FLIGHT SOFTWARE	=	1246[illegible]	92.5	347412.9
UNUSED MANHOURS	=	70[illegible].7	[illegible].0	1417534.3
TOTAL OPS. HOURS	=	124[illegible]	924.6	
TOTAL OPS. COSTS	=	29[illegible]	354122.6	3162123.6

OPERATIONS PER/FLT COSTS = 451732.7

OPTION	=	3		
YEAR	=	1982		
NUMBER OF FLIGHTS	=	10,0		
AUTONOMY LEVEL	=	4,0		
DOD MISSION				
MISSION DURATION	=	39,8		
LAUNCH FROM WTR	=	0,0		
LAUNCH FROM ETR	=	10,0		

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	22395,5	205,6	536639,6
FLIGHT CONTROL	=	84377,2	707,3	1968440,8
FLIGHT EVALUATION	=	17027,3	224,0	426355,2
FLIGHT SOFTWARE	=	12480,[illegible]	126,3	35[illegible]381,7
UNUSED MANHOURS	=	54723,1	0,0	1084462,0
TOTAL OPS, HOURS	=	1249[illegible]	1263,2	
TOTAL OPS, COSTS	=	2328[illegible]	463817,4	3291817,4

OPERATIONS PER/FLT COSTS = 329181,7

OPTION = 3

YEAR = 1983

NUMBER OF FLIGHTS = 16.0 17

AUTONOMY LEVEL = 4.0

DOD MISSION

MISSION DURATION = 42.9

LAUNCH FROM WTR = 4.0

LAUNCH FROM ETR = 12.0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	27571.8	255.3	651192.6
FLIGHT CONTROL	=	69263.0	1178.6	1836647.4
FLIGHT EVALUATION	=	27065.5	366.7	697736.3
FLIGHT SOFTWARE	=	1248[illegible]	200.1	388619.6
UNUSED MANHOURS	=	18629.8	0.0	372590.5
TOTAL OPS. HOURS	=	1243[illegible]	2000.5	
TOTAL OPS. COSTS	=	[illegible]	766195.9	3574195.9

OPERATIONS PER/FLT COSTS = 223387.2

:

OPTION	=	3
YEAR	=	1984
NUMBER OF FLIGHTS	=	18.0
AUTONOMY LEVEL	=	4.0
DOD MISSION		
MISSION DURATION	=	4[illegible].6
LAUNCH FROM WTR	=	1.0
LAUNCH FROM ETR	=	17.0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	31584.3	285.5	721027.9
FLIGHT CONTROL	=	63306.[illegible]	1299.1	1765279.2
FLIGHT EVALUATION	=	33927.7	405.7	771959.1
FLIGHT SOFTWARE	=	12400.[illegible]	221.1	396696.3
UNUSED MANHOURS	=	4453.2	0.0	89064.6
TOTAL OPS. HOURS	=	1248[illegible].[illegible]	2211.4	
TOTAL OPS. COSTS	=	2[illegible]	846962.5	3634962.5

OPERATIONS PER/FLT COSTS = [illegible]3053.5

OPTION	=	3
YEAR	=	1985
NUMBER OF FLIGHTS	=	13.0
AUTONOMY LEVEL	=	3.0
DOD MISSION		
MISSION DURATION	=	48.5
LAUNCH FROM WTR	=	2.0
LAUNCH FROM ETR	=	11.0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	32143,2	261,4	743089,0
FLIGHT CONTROL	=	40122,1	765,9	1095789,3
FLIGHT EVALUATION	=	39755,4	309,9	903803,5
FLIGHT SOFTWARE	=	11452,6	143,6	335721,9
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS. HOURS	=	111526,3	1485,8	
TOTAL OPS. COSTS	=	2509342,6	569061,0	3078403,6

OPERATIONS PER/FLT COSTS = 236800,3

OPTION = 3

YEAR = 1986

NUMBER OF FLIGHTS = 17.0

AUTONOMY LEVEL = 3.0

DOD MISSION

MISSION DURATION = 36.4

LAUNCH FROM WTR = 5.0

LAUNCH FROM ETR = 12.0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	36364.4	302.3	843084.7
FLIGHT CONTROL	=	46192.2	853.2	1270635.8
FLIGHT EVALUATION	=	38169.9	371.3	926020.7
FLIGHT SOFTWARE	=	12274.2	162.6	371845.7
UNUSED MANHOURS	=	0.0	0.0	0.0
TOTAL OPS. HOURS	=	122743.1	1695.5	
TOTAL OPS. COSTS	=	2761832.6	649754.3	3411586.9

OPERATIONS PER/FLT COSTS = 200681.6

OPTION = 3

YEAR = 1987

NUMBER OF FLIGHTS = 16.0

AUTONOMY LEVEL = 3.0

DOD MISSION

MISSION DURATION = 47.3

LAUNCH FROM WTR = 2.0

LAUNCH FROM ETR = 14.0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	35482.5	293.3	822114.8
FLIGHT CONTROL	=	43948.9	925.0	1331341.3
FLIGHT EVALUATION	=	43733.6	378.3	959546.2
FLIGHT SOFTWARE	=	12517.2	175.8	336659.1
UNUSED MANHOURS	=	0.0	0.0	0.0
TOTAL OPS. HOURS	=	125172.8	1766.4	
TOTAL OPS. COSTS	=	2816369.5	677291.9	3429661.4

OPERATIONS PER/FLT COSTS = 214353.8

OPTION = 3

YEAR = 1989

NUMBER OF FLIGHTS = 18,0

AUTONOMY LEVEL = 3,0

DOD MISSION

MISSION DURATION = 39,1

LAUNCH FROM WTR = 2,0

LAUNCH FROM ETR = 16,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	38[illegible]62,2	314,6	881738,6
FLIGHT CONTROL	=	50331,1	888,9	1347077,3
FLIGHT EVALUATION	=	39533,[illegible]	401,2	944330,0
FLIGHT SOFTWARE	=	12792,7	178,3	388107,3
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS, HOURS	=	127725,[illegible]	1783,0	
TOTAL OPS, COSTS	=	2873753,2	682892,7	3551252,9

OPERATIONS PER/FLT COSTS = 197847,4

OPTION = 3

YEAR = 1980

NUMBER OF FLIGHTS = 16.0

AUTONOMY LEVEL = 3.0

DOD MISSION

MISSION DURATION = 51.2

LAUNCH FROM WTR = 4.0

LAUNCH FROM ETR = 12.0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	36220.6	295.9	837904.5
FLIGHT CONTROL	=	48483.7	910.3	1318312.8
FLIGHT EVALUATION	=	41041.0	388.6	935653.8
FLIGHT SOFTWARE	=	12659.4	177.2	384250.7
UNUSED MANHOURS	=	0.0	0.0	0.0
TOTAL OPS. HOURS	=	126854.2	1771.9	
TOTAL OPS. COSTS	=	2847461.0	678658.1	3526121.9

OPERATIONS PER/FLT COSTS = 220382.6

OPTION = 3

YEAR = 199[illegible]

NUMBER OF FLIGHTS = 18,0

AUTONOMY LEVEL = 3,0

DOD MISSION

MISSION DURATION = 40,7

LAUNCH FROM WTR = 1,0

LAUNCH FROM ETR = 17,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MAN HOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	3[illegible]4[illegible]2,4	314,3	831153,6
FLIGHT CONTROL	=	50[illegible]2,3	906,4	1363214,6
FLIGHT EVALUATION	=	40[illegible],6	404,0	9[illegible]5510,6
FLIGHT SOFTWARE	=	12384,[illegible]	18[illegible],7	391331,9
UNUSED MANHOURS	=	[illegible]	0,0	0,0
TOTAL OPS. HOURS	=	12[illegible]43,4	1807,4	
TOTAL OPS. COSTS	=	2398[illegible]7[illegible],[illegible]	692233,5	3591210,7

OPERATIONS PER/FLT COSTS = 19[illegible]511,7

TOTAL PROGRAM COSTS

NUMBER OF FLIGHTS =149.0

AUTONOMY LEVEL = 3.0

DOD MISSION

LAUNCH FROM WTR = 21.0

LAUNCH FROM ETR =128.0

FLIGHT OPERATIONS RECURRING COSTS (DOD ONLY)

	MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING =	318094.8	2709.8	7399735.0
FLIGHT CONTROL =	396696.2	8923.6	15331655.4
FLIGHT EVALUATION =	327179.8	3408.2	7848924.6
FLIGHT SOFTWARE =	124197.1	1671.3	3745026.9
UNUSED MANHOURS =	148182.6	0.0	2963651.4
TOTAL OPS. HOURS =	1241273.8	16712.8	
TOTAL OPS. COSTS =	27944344.0	6400998.0	34345341.9

OPERATIONS PER/FLT COSTS = 230505.7

FLIGHT OPERATIONS NON-RECURRING COSTS (TOTAL PROGRAM FOR BOTH DOD & NASA)

	MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING =	478264.6	2008.0	11543527.2
FLIGHT CONTROL =	52263.9	0.0	1175938.2
FLIGHT EVALUATION =	0.0	0.0	0.0
FLIGHT SOFTWARE =	178005.2	3122.3	5200963.6
TOTAL DDT E HOURS =	709133.7	5130.3	
TOTAL DDT E COSTS =	15955509.0	1964904.9	17920429.0

The Work Breakdown Structure for the Tug Study divides the flight operations into four areas or blocks, namely: Mission Planning, Flight Control, Flight Evaluation, and Flight Support Software. In order to develop a means of assessing the relative complexity of flight operations for various Tug configurations, it was first necessary to adequately define flight operations. This was accomplished by analyzing the four WBS blocks to determine the specific tasks required in each. These tasks fell into three categories: one time efforts completed prior to the first operational flight, a continuing level of effort for the operational life of the program, and those efforts performed once for each flight. The one time efforts were considered to be part of the DDT&E activities (32A) while the continuing and per flight efforts were assigned to the Operations activities (32C). With this format developed, a reference configuration was chosen (Number 101) and an estimate was made of the manhours and computer time required to accomplish each flight operations task considering the specific characteristics of that configuration.

With the reference configuration estimates determined as a point of departure, it was necessary to establish criteria or a rationale for assessing the operational workload differences between configurations. An analysis of this area concluded that the workload was proportional to the operational complexity of the configuration and the mission. It was also decided that the configuration complexity could primarily be measured by autonomy level and the mission complexity by mission duration. Since the reference configuration was autonomy Level IV (completely dependent on ground support/simple onboard equipment), Level IV was given a reference value of 1.0 and the other levels given relative values to reflect the degree of difference. When autonomy level was used to measure workload related to ground support dependence, the workload decreased with increasing autonomy levels and values were assigned as shown below. It was assumed that ground support effort would not be charged to highly autonomous configurations not requiring that support even though experience indicates that it may be required for some other reason. Some task workloads are proportional to the complexity of onboard equipment and therefore increase with increasing autonomy levels. (Level II was considered the highest level because of the additional mission planning capability.) Values were also assigned as shown below:

AUTONOMY LEVEL	EQUIPMENT COMPLEXITY VALUE	DEPENDENCE ON GROUND SUPPORT VALUE
IV	1.0	1.00
III	1.5	.67
I	2.0	.50
II	2.5	.40

Since the reference configuration was a minimum (1 day) mission configuration, a reference value of 1.0 was given to the 1 day duration and the other durations were assigned relative values as follows:

MISSION DURATION

DAYS	VALUE
1	1.0
1.5	1.1
3	1.4
6	2.0

Assignment of these values take into account the fact that a configuration capable of longer duration missions does not fly all long duration missions and the average mission length is actually shorter. To obtain a more precise assessment of the effect of mission duration, actual mission time in hours for each flight can be used in lieu of the single mission duration factor value above.

Some tasks must be performed for each flight and, therefore, the reference configuration estimate (per flight) must be multiplied by the number of flights.

For those configurations where phasing occurs from an initial to a final configuration, the continuing level of effort tasks were factored for the number of years the configuration is to be operational. Since the total operational program is eleven years and the configurations are operational for either four, seven, or eleven years, the following values were assigned:

PROGRAM DURATION

OPERATIONAL YEARS	VALUE
11	1.0
7	0.7
4	0.4

While the program duration factor proportions the effort between two phased configurations, it does not take into consideration that many of the efforts completed for the initial configuration must be repeated for the final configuration. To take this into account a factor was established as follows:

DEVELOPMENT PROGRAM

DIRECT DEVELOPMENT VALUE	PHASED PROGRAM VALUE
1.0	1.7

Since the reference configuration did not have retrieval capability additional complexity is introduced by those configurations having rendezvous, docking and payload spin up capability. Appropriate values were assigned to these factors:

RENDEZVOUS AND DOCKING		PAYLOAD SPIN-UP CAPABILITY	
NOT REQUIRED	REQUIRED	NOT REQUIRED	REQUIRED
1.0	1.2	1.0	1.04

With all the complexity factors defined, an assessment was made for each task to determine which factors affected the effort required relative to the reference configuration and how they varied. A summary matrix of the tasks and factors is shown on a following page.

Using the manhours and computer hours estimated for the reference configuration and applying the appropriate factors to each operations task, equations were prepared which could be computed and summed to provide the total flight operations effort for any Tug program or configuration. A computer program incorporating these equations was developed to provide maximum flexibility in determining flight operations efforts for various programs and trade studies. Separate manhours, computer hours and dollar costs are computed for each WBS element (Mission Planning, Flight Control, Flight Evaluation and Flight Support Software) in the DDT&E (WBS 32A) and the Operations (WBS 32C) areas. The Operations estimates are computed for each year of the operational program and totaled. The NASA and DOD figures are computed separately.

SENSITIVITIES FOR FLIGHT OPERATIONS FUNCTIONS

WBS 320-11/12

W B S L E V E L S	AUTONOMY LEVEL	MISSION DURATION	NUMBER OF FLIGHTS	PROGRAM DURATION	PROGRAM PHASING	RENDEZVOUS & DOCKING	SPIN-UP
MISSION PLANNING (320-11/12-01)							
o FLIGHT PLAN	N.A.	INCREASES	MULTIPLE	N.A.	N.A.	INCREASES	M.D.
o MALFUNCTION ANALYSIS	INCREASES	N.A.	N.A.	MULTIPLE	INCREASES	INCREASES	INCREASES
o ABORT PROFILES	INCREASES	N.A.	MULTIPLE	N.A.	INCREASES	INCREASES	INCREASES
o MISSION RULES	N.A.	N.A.	N.A.	MULTIPLE	INCREASES	INCREASES	INCREASES
o COMMAND HANDBOOK	DECREASES	N.A.	N.A.	N.A.	INCREASES	INCREASES	INCREASES
o PROCEDURES AND CHECKLISTS	INCREASES	N.A.	N.A.	MULTIPLE	INCREASES	INCREASES	INCREASES
o INSTRUMENTATION LIST	N.A.	N.A.	N.A.	MULTIPLE	INCREASES	INCREASES	INCREASES
o OPERATIONAL DATA BOOK	INCREASES	N.A.	N.A.	N.A.	INCREASES	INCREASES	INCREASES
o SYSTEM SCHEMATICS	INCREASES	N.A.	N.A.	N.A.	INCREASES	INCREASES	INCREASES
o INTERFACE DRAWINGS	INCREASES	N.A.	N.A.	MULTIPLE	INCREASES	INCREASES	INCREASES
o SCHEDULES	N.A.	N.A.	N.A.	MULTIPLE	N.A.	N.A.	N.A.
FLIGHT CONTROL (320-11/12/02)							
o CONTROL REQUIREMENTS	DECREASES	INCREASES	MULTIPLE	N.A.	N.A.	INCREASES	INCREASES
o CONTROL ANALYSIS	N.A.	INCREASES	MULTIPLE	N.A.	N.A.	INCREASES	INCREASES
o PLANNING	DECREASES	N.A.	N.A.	N.A.	INCREASES	INCREASES	N.A.
o FLIGHT CONTROL	DECREASES	INCREASES	MULTIPLE	N.A.	N.A.	N.A.	N.A.
o ANALYSIS ANOMALIES	DECREASES	INCREASES	MULTIPLE	N.A.	N.A.	N.A.	N.A.
o CHECKOUT	DECREASES	N.A.	MULTIPLE	N.A.	N.A.	N.A.	N.A.
o ACTIVATION	DECREASES	N.A.	MULTIPLE	N.A.	N.A.	N.A.	N.A.
FLIGHT EVALUATION (320-11/12-03)							
o DATA REDUCTION	N.A.	INCREASES	MULTIPLE	N.A.	N.A.	N.A.	N.A.
o DATA ANALYSIS	N.A.	INCREASES	MULTIPLE	N.A.	N.A.	N.A.	N.A.
o RESOLVE ANOMALIES	N.A.	INCREASES	MULTIPLE	N.A.	N.A.	N.A.	N.A.
o REPORT	N.A.	INCREASES	MULTIPLE	N.A.	N.A.	N.A.	N.A.
FLIGHT SUPPORT SOFTWARE (320-11/12-04)							
o PLANNING	N.A.	N.A.	N.A.	N.A.	N.A.	INCREASES	N.A.
o FLIGHT CONTROL	DECREASES	N.A.	N.A.	N.A.	N.A.	INCREASES	INCREASES
o SIMULATIONS	DECREASES	INCREASES	N.A.	N.A.	N.A.	INCREASES	INCREASES
o FLIGHT SUPPORT	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
o CONTROL SUPPORT	INCREASES	N.A.	N.A.	N.A.	N.A.	INCREASES	INCREASES
o FLIGHT EVALUATION	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

The Operations tasks were further analyzed in terms of actual people and skills required. It was determined that a minimum operations crew (one for each of three shifts) was required for flight control of only one Tug flight. These crews are capable of handling a significant number of flights per month; a greater number than sometimes required by the mission model. Even though these crews are utilized to perform the mission planning, flight evaluation and flight support software tasks in addition to their flight control requirements, there is sometimes an excess of manhours available. In order to allow for this, the manhours available from the minimum crews are incorporated into the computer program as minimum for the 32C area. When the actual manhours requirements are calculated, if the total does not exceed the minimum,then the minimum is used and the unused manhours are shown. This minimum crew is required for both NASA and DOD.

Option 3 is a phased program consisting of two distant configurations. The initial configuration is operational for four years before the final configuration is introduced and overlaps the final configuration operational period by 4 years for NASA Tugs and 3 years for DOD Tugs. The final configuration has a seven year operational life. The initial configuration has a level IV autonomy, a 3 day mission duration and no rendezvous, docking or spin-up capability. The final configuration has a level III autonomy, a 6 day mission duration and has rendezvous, docking and spin-up capabilities. The appropriate factors including proportional values for the years during the overlap of the two configurations, the number of flights and the mission times were input into the computer program. The results of the calculations are shown in Section 4.

A variation of Option 3 which was examined was a 2 year delay in the operational date thereby shortening the program duration from 11 to 9 years. The numbers of flights per year and mission times were affected. The appropriate changes were made to these quantities in the computer inputs and the results of this run are shown in the following pages.

OPTION	=	3 - LATE IOC
YEAR	=	1982
NUMBER OF FLIGHTS	=	12,0
AUTONOMY LEVEL	=	4,0
NASA MISSION		
MISSION DURATION	=	40,5
LAUNCH FROM WTR	=	0,0
LAUNCH FROM ETR	=	12,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	24452,3	221,8	573980,6
FLIGHT CONTROL	=	79809,6	856,7	1924308,2
FLIGHT EVALUATION	=	20538,1	270,2	514262,8
FLIGHT SOFTWARE	=	12480,0	149,9	369394,6
UNUSED MANHOURS	=	42755,9	0,0	855118,3
TOTAL OPS, HOURS	=	124800,0	1498,6	
TOTAL OPS, COSTS	=	2808800,0	573946,2	3381946,2

OPERATIONS PER/FLT COSTS = 281828,9

OPTION = 3

YEAR = 1987

NUMBER OF FLIGHTS = 20,0

AUTONOMY LEVEL = 4,0

NASA MISSION

MISSION DURATION = 38,4

LAUNCH FROM WTR = 4,0

LAUNCH FROM ETR = 16,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	30377,1	283,4	716085,8
FLIGHT CONTROL	=	60719,2	1386,1	1746044,7
FLIGHT EVALUATION	=	33703,7	443,5	843922,1
FLIGHT SOFTWARE	=	12480,0	235,0	402005,8
UNUSED MANHOURS	=	306,9	0,0	6138,4
TOTAL OPS. HOURS	=	124800,0	2350,0	
TOTAL OPS. COSTS	=	2808000,0	900058,5	3708058,5

OPERATIONS PER/FLT COSTS = 185402,9

OPTION = 3

YEAR = 1984

NUMBER OF FLIGHTS = 26.0

AUTONOMY LEVEL = 3.0

NASA MISSION

MISSION DURATION = 39.0

LAUNCH FROM WTR = 4.0

LAUNCH FROM ETR = 22.0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	42554.3	373.2	994007.0
FLIGHT CONTROL	=	79321.6	1514.8	2166618.0
FLIGHT EVALUATION	=	44021.6	579.1	1102221.0
FLIGHT SOFTWARE	=	16589.7	274.1	519732.2
UNUSED MANHOURS	=	0.0	0.0	0.0
TOTAL OPS. HOURS	=	165897.5	2741.2	
TOTAL OPS. COSTS	=	3732693.7	1049884.4	4782578.1

OPERATIONS PER/FLT COSTS = 183945.3

OPTION = 3

YEAR = 1988

NUMBER OF FLIGHTS = 28,0

AUTONOMY LEVEL = 3,0

NASA MISSION

MISSION DURATION = 39,0

LAUNCH FROM WTR = 6,0

LAUNCH FROM ETR = 22,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	44452,6	392,7	1043585,0
FLIGHT CONTROL	=	84754,9	1612,0	2312485,4
FLIGHT EVALUATION	=	47031,7	623,6	1179484,1
FLIGHT SOFTWARE	=	17644,6	292,0	552963,2
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS, HOURS	=	176443,8	2920,3	
TOTAL OPS, COSTS	=	3970029,4	1118488,3	5088517,7

OPERATIONS PER/FLT COSTS = 181732,8

OPTION = 3

YEAR = 1986

NUMBER OF FLIGHTS = 24,0

AUTONOMY LEVEL = 3,0

NASA MISSION

MISSION DURATION = 36,7

LAUNCH FROM WTR = 4,0

LAUNCH FROM ETR = 20,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	39385,7	345,1	931056,6
FLIGHT CONTROL	=	71649,3	1370,5	1957929,7
FLIGHT EVALUATION	=	42161,7	525,4	1044475,6
FLIGHT SOFTWARE	=	15369,8	249,3	470745,1
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS, HOURS	=	133697,7	2493,3	
TOTAL OPS, COSTS	=	3458198,6	955008,2	4413206,9

OPERATIONS PER/FLT COSTS = 183883,6

OPTION = 3

YEAR = 1987

NUMBER OF FLIGHTS = 24,0

AUTONOMY LEVEL = 3,0

NASA MISSION

MISSION DURATION = 45,8

LAUNCH FROM WTR = 6,0

LAUNCH FROM ETR = 18,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	41182,1	357,3	962561,5
FLIGHT CONTROL	=	76006,2	1492,6	2091784,8
FLIGHT EVALUATION	=	45052,2	561,5	1116080,5
FLIGHT SOFTWARE	=	16224,6	267,3	506225,3
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS, HOURS	=	162240,5	2679,5	
TOTAL OPS, COSTS	=	3650411,1	1026241,1	4676652,1

OPERATIONS PER/FLT COSTS = 194860,5

OPTION = 3

YEAR = 1980

NUMBER OF FLIGHTS = 19,0

AUTONOMY LEVEL = 3,0

NASA MISSION

MISSION DURATION = 48,6

LAUNCH FROM WTR = 4,0

LAUNCH FROM ETR = 15,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	37998,7	320,7	882821,1
FLIGHT CONTROL	=	59849,7	1147,9	1636653,0
FLIGHT EVALUATION	=	42917,5	453,3	1031947,8
FLIGHT SOFTWARE	=	14676,6	213,5	433704,0
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS, HOURS	=	140765,8	2135,5	
TOTAL OPS, COSTS	=	3147230,8	817895,1	3985125,9

OPERATIONS PER/FLT COSTS = 209743,5

OPTION = 3

YEAR = 1989

NUMBER OF FLIGHTS = 25,0

AUTONOMY LEVEL = 3,0

NASA MISSION

MISSION DURATION = 35,4

LAUNCH FROM WTR = 5,0

LAUNCH FROM ETR = 20,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	41678,6	354,8	957440,5
FLIGHT CONTROL	=	70412,7	1328,2	1916958,8
FLIGHT EVALUATION	=	42298,4	542,0	1053541,5
FLIGHT SOFTWARE	=	15378,9	247,2	479152,1
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS. HOURS	=	153789,2	2472,2	
TOTAL OPS. COSTS	=	3460256,6	946841,9	4407097,9

OPERATIONS PER/FLT COSTS = 176283,9

OPTION = 3

YEAR = 1990

NUMBER OF FLIGHTS = 22,0

AUTONOMY LEVEL = 3,0

NASA MISSION

MISSION DURATION = 37,5

LAUNCH FROM WTR = 4,0

LAUNCH FROM ETR = 18,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	41463,2	340,1	963101,3
FLIGHT CONTROL	=	59844,0	1060,7	1603115,0
FLIGHT EVALUATION	=	41299,6	484,6	1011563,5
FLIGHT SOFTWARE	=	14263,4	218,4	437150,9
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS. HOURS	=	142831,2	2103,7	
TOTAL OPS. COSTS	=	3209202,4	805728,3	4014930,7

OPERATIONS PER/FLT COSTS = 182496,8

OPTION = 3 - LATE IOC

TOTAL PROGRAM COSTS

NUMBER OF FLIGHTS = 200.0

AUTONOMY LEVEL = 3.0

NASA MISSION

LAUNCH FROM WTR = 37.0

LAUNCH FROM ETR = 163.0

FLIGHT OPERATIONS RECURRING COSTS (NASA ONLY)

	MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING =	343676.7	3000.3	8022639.3
FLIGHT CONTROL =	642367.2	11771.7	17355897.7
FLIGHT EVALUATION =	359023.9	4483.0	8897498.8
FLIGHT SOFTWARE =	134506.8	2139.4	4182078.3
UNUSED MANHOURS =	43063.1	0.0	861256.8
TOTAL OPS. HOURS =	1345067.7	21394.5	
TOTAL OPS. COSTS =	30264022.2	8194091.9	38458114.1

OPERATIONS PER/FLT COSTS = 192290.6

FLIGHT OPERATIONS NON-RECURRING COSTS (TOTAL PROGRAM FOR BOTH DOD & NASA)

	MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING =	478864.6	2008.0	11543527.2
FLIGHT CONTROL =	52263.9	0.0	1175938.2
FLIGHT EVALUATION =	0.0	0.0	0.0
FLIGHT SOFTWARE =	178005.2	3122.3	5200963.6
TOTAL DDT E HOURS =	709133.7	5130.3	
TOTAL DDT E COSTS =	15955509.0	1964904.9	17920429.0

OPTION	=	3 - LATE IOC
YEAR	=	1982
NUMBER OF FLIGHTS	=	10,0
AUTONOMY LEVEL	=	4,0
DOD MISSION		
MISSION DURATION	=	39,8
LAUNCH FROM WTR	=	0,0
LAUNCH FROM ETR	=	10,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	22395,5	205,6	536639,6
FLIGHT CONTROL	=	84877,2	707,3	1968440,8
FLIGHT EVALUATION	=	17027,3	224,0	426355,2
FLIGHT SOFTWARE	=	12480,0	124,3	360381,7
UNUSED MANHOURS	=	54223,1	0,0	1084462,0
TOTAL OPS, HOURS	=	124800,0	1263,2	
TOTAL OPS, COSTS	=	2808000,0	483817,4	3291817,4

OPERATIONS PER/FLT COSTS = 329181,7

OPTION = 3

YEAR = 1983

NUMBER OF FLIGHTS = 16,0 17

AUTONOMY LEVEL = 4,0

DOD MISSION

MISSION DURATION = 42,9

LAUNCH FROM WTR = 4,0

LAUNCH FROM ETR = 12,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	27571,8	255,3	651192,6
FLIGHT CONTROL	=	69263,6	1178,6	1836647,4
FLIGHT EVALUATION	=	27865,5	366,7	697736,3
FLIGHT SOFTWARE	=	12480,0	200,1	388619,6
UNUSED MANHOURS	=	18629,5	0,0	372590,5
TOTAL OPS, HOURS	=	124800,0	2000,5	
TOTAL OPS, COSTS	=	2808000,0	766195,9	3574195,9

OPERATIONS PER/FLT COSTS = 223387,2

OPTION = 3

YEAR = 1984

NUMBER OF FLIGHTS = 18.0

AUTONOMY LEVEL = 4.0

DOD MISSION

MISSION DURATION = 40.6

LAUNCH FROM WTR = 1.0

LAUNCH FROM ETR = 17.0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	30584.3	285.5	721027.9
FLIGHT CONTROL	=	63306.0	1299.1	1765279.2
FLIGHT EVALUATION	=	30829.7	405.7	771959.1
FLIGHT SOFTWARE	=	12480.0	221.1	396696.3
UNUSED MANHOURS	=	4453.2	0.0	89064.6
TOTAL OPS. HOURS	=	124800.0	2211.4	
TOTAL OPS. COSTS	=	2808000.0	846962.5	3654962.5

OPERATIONS PER/FLT COSTS = 203053.5

OPTION = 3

YEAR = 1985

NUMBER OF FLIGHTS = 13,0

AUTONOMY LEVEL = 3,0

DOD MISSION

MISSION DURATION = 48,5

LAUNCH FROM WTR = 2,0

LAUNCH FROM ETR = 11,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	32148,9	261,4	743089,6
FLIGHT CONTROL	=	40122,1	765,9	1095789,3
FLIGHT EVALUATION	=	39255,4	309,9	903803,5
FLIGHT SOFTWARE	=	11152,6	148,6	335721,9
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS, HOURS	=	111526,3	1485,8	
TOTAL OPS, COSTS	=	2309342,6	569061,0	3078403,6

OPERATIONS PER/FLT COSTS = 236800,3

OPTION = 3

YEAR = 1986

NUMBER OF FLIGHTS = 17,0

AUTONOMY LEVEL = 3,0

DOD MISSION

MISSION DURATION = 36,4

LAUNCH FROM WTR = 5,0

LAUNCH FROM ETR = 12,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	36366,1	302,3	843084,7
FLIGHT CONTROL	=	48192,2	853,2	1290635,8
FLIGHT EVALUATION	=	38189,9	371,3	936020,7
FLIGHT SOFTWARE	=	12274,9	169,6	371845,7
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS. HOURS	=	122749,1	1696,5	
TOTAL OPS. COSTS	=	2761832,6	649754,3	3411586,9

OPERATIONS PER/FLT COSTS = 200681,6

OPTION	= 3		
YEAR	= 1987		
NUMBER OF FLIGHTS	= 16.0		
AUTONOMY LEVEL	= 3.0		
DOD MISSION			
MISSION DURATION	= 47.3		
LAUNCH FROM WTR	= 2.0		
LAUNCH FROM ETR	= 14.0		

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

	MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING =	35482.5	293.3	822114.8
FLIGHT CONTROL =	48948.9	920.0	1331341.3
FLIGHT EVALUATION =	40733.6	378.3	959546.2
FLIGHT SOFTWARE =	12317.2	176.8	330659.1
UNUSED MANHOURS =	0.0	0.0	0.0
TOTAL OPS. HOURS =	125172.0	1768.4	
TOTAL OPS. COSTS =	2816369.3	677291.9	3443661.4

OPERATIONS PER/FLT COSTS = 215353.8

OPTION = 3

YEAR = 1988

NUMBER OF FLIGHTS = 18,0

AUTONOMY LEVEL = 3,0

DOD MISSION

MISSION DURATION = 39,1

LAUNCH FROM WTR = 2,0

LAUNCH FROM ETR = 16,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	38062,2	314,6	881738,6
FLIGHT CONTROL	=	50331,1	888,9	1347077,3
FLIGHT EVALUATION	=	39533,5	401,2	944330,0
FLIGHT SOFTWARE	=	12792,7	178,3	338107,0
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS, HOURS	=	127926,8	1783,0	
TOTAL OPS, COSTS	=	2878353,2	682899,7	3561252,9

OPERATIONS PER/FLT COSTS = 197847,4

OPTION = 3

YEAR = 1989

NUMBER OF FLIGHTS = 16,0

AUTONOMY LEVEL = 3,0

DOD MISSION

MISSION DURATION = 51,2

LAUNCH FROM WTR = 4,0

LAUNCH FROM ETR = 12,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	36229,6	295,9	837904,5
FLIGHT CONTROL	=	48483,7	910,3	1318312,8
FLIGHT EVALUATION	=	41841,9	388,6	985653,8
FLIGHT SOFTWARE	=	12658,4	177,2	384250,7
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS, HOURS	=	126554,2	1771,9	
TOTAL OPS, COSTS	=	2847468,8	678653,1	3526121,9

OPERATIONS PER/FLT COSTS = 220382,6

OPTION = 3

YEAR = 1990

NUMBER OF FLIGHTS = 18,0

AUTONOMY LEVEL = 3,0

DOD MISSION

MISSION DURATION = 40.7

LAUNCH FROM WTR = 1,0

LAUNCH FROM ETR = 17,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MAN HOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	32632,4	314,3	881153,6
FLIGHT CONTROL	=	50802,3	906,4	1363214,6
FLIGHT EVALUATION	=	40001,6	404,0	955510,6
FLIGHT SOFTWARE	=	12384,3	186,7	321331,9
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS, HOURS	=	125843,4	1807,4	
TOTAL OPS, COSTS	=	2808977,2	692233,5	3521210,7

OPERATIONS PER/FLT COSTS = 199511,7

OPTION = 3 - LATE IOC

TOTAL PROGRAM COSTS

NUMBER OF FLIGHTS = 142.0

AUTONOMY LEVEL = 3.0

DOD MISSION

LAUNCH FROM WTR = 21.0

LAUNCH FROM ETR = 121.0

FLIGHT OPERATIONS RECURRING COSTS (DOD ONLY)

	MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING =	297486.2	2528.0	6917945.4
FLIGHT CONTROL =	504406.4	8429.8	13316738.5
FLIGHT EVALUATION =	315278.2	3251.6	7550915.4
FLIGHT SOFTWARE =	111717.1	1578.8	3397614.0
UNUSED MANHOURS =	77305.9	0.0	1546117.1
TOTAL OPS. HOURS =	1117170.8	15788.2	
TOTAL OPS. COSTS =	25136344.0	6046869.4	31183213.3

OPERATIONS PER/FLT COSTS = 219600.1

FLIGHT OPERATIONS NON-RECURRING COSTS (TOTAL PROGRAM FOR BOTH DOD & NASA)

	MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING =	~~478264.6~~	~~2008.0~~	~~11543527.2~~
FLIGHT CONTROL =	52263.9	0.0	1175938.2
FLIGHT EVALUATION =	0.0	0.0	0.0
FLIGHT SOFTWARE =	178005.2	3122.3	5200963.6
TOTAL DDT E HOURS =	709133.7	5130.3	
TOTAL DDT E COSTS =	15955509.0	1964904.9	17920429.0

The Work Breakdown Structure for the Tug Study divides the flight operations into four areas or blocks, namely: Mission Planning, Flight Control, Flight Evaluation, and Flight Support Software. In order to develop a means of assessing the relative complexity of flight operations for various Tug configurations, it was first necessary to adequately define flight operations. This was accomplished by analyzing the four WBS blocks to determine the specific tasks required in each. These tasks fell into three categories: one time efforts completed prior to the first operational flight, a continuing level of effort for the operational life of the program, and those efforts performed once for each flight. The one time efforts were considered to be part of the DDT&E activities (32A) while the continuing and per flight efforts were assigned to the Operations activities (32C). With this format developed, a reference configuration was chosen (Number 101) and an estimate was made of the manhours and computer time required to accomplish each flight operations task considering the specific characteristics of that configuration.

With the reference configuration estimates determined as a point of departure, it was necessary to establish criteria or a rationale for assessing the operational workload differences between configurations. An analysis of this area concluded that the workload was proportional to the operational complexity of the configuration and the mission. It was also decided that the configuration complexity could primarily be measured by autonomy level and the mission complexity by mission duration. Since the reference configuration was autonomy Level IV (completely dependent on ground support/simple onboard equipment), Level IV was given a reference value of 1.0 and the other levels given relative values to reflect the degree of difference. When autonomy level was used to measure workload related to ground support dependence, the workload decreased with increasing autonomy levels and values were assigned as shown below. It was assumed that ground support effort would not be charged to highly autonomous configurations not requiring that support even though experience indicates that it may be required for some other reason. Some task workloads are proportional to the complexity of onboard equipment and therefore increase with increasing autonomy levels. (Level II was considered the highest level because of the additional mission planning capability.) Values were also assigned as shown below:

AUTONOMY LEVEL	EQUIPMENT COMPLEXITY VALUE	DEPENDENCE ON GROUND SUPPORT VALUE
IV	1.0	1.00
III	1.5	.67
I	2.0	.50
II	2.5	.40

Since the reference configuration was a minimum (1 day) mission configuration, a reference value of 1.0 was given to the 1 day duration and the other durations were assigned relative values as follows:

MISSION DURATION

DAYS	VALUE
1	1.0
1.5	1.1
3	1.4
6	2.0

Assignment of these values take into account the fact that a configuration capable of longer duration missions does not fly all long duration missions and the average mission length is actually shorter. To obtain a more precise assessment of the effect of mission duration, actual mission time in hours for each flight can be used in lieu of the single mission duration factor value above.

Some tasks must be performed for each flight and, therefore, the reference configuration estimate (per flight) must be multiplied by the number of flights.

For those configurations where phasing occurs from an initial to a final configuration, the continuing level of effort tasks were factored for the number of years the configuration is to be operational. Since the total operational program is eleven years and the configurations are operational for either four, seven, or eleven years, the following values were assigned:

PROGRAM DURATION

OPERATIONAL YEARS	VALUE
11	1.0
7	0.7
4	0.4

While the program duration factor proportions the effort between two phased configurations, it does not take into consideration that many of the efforts completed for the initial configuration must be repeated for the final configuration. To take this into account a factor was established as follows:

DEVELOPMENT PROGRAM	
DIRECT DEVELOPMENT VALUE	PHASED PROGRAM VALUE
1.0	1.7

Since the reference configuration did not have retrieval capability additional complexity is introduced by those configurations having rendezvous, docking and payload spin up capability. Appropriate values were assigned to these factors:

RENDEZVOUS AND DOCKING		PAYLOAD SPIN-UP CAPABILITY	
NOT REQUIRED	REQUIRED	NOT REQUIRED	REQUIRED
1.0	1.2	1.0	1.04

With all the complexity factors defined, an assessment was made for each task to determine which factors affected the effort required relative to the reference configuration and how they varied. A summary matrix of the tasks and factors is shown on a following page.

Using the manhours and computer hours estimated for the reference configuration and applying the appropriate factors to each operations task, equations were prepared which could be computed and summed to provide the total flight operations effort for any Tug program or configuration. A computer program incorporating these equations was developed to provide maximum flexibility in determining flight operations efforts for various programs and trade studies. Separate manhours, computer hours and dollar costs are computed for each WBS element (Mission Planning, Flight Control, Flight Evaluation and Flight Support Software) in the DDT&E (WBS 32A) and the Operations (WBS 32C) areas. The Operations estimates are computed for each year of the operational program and totaled. The NASA and DOD figures are computed separately.

SENSITIVITIES FOR FLIGHT OPERATIONS FUNCTIONS

WBS 320-11/12

WBS LEVELS	AUTONOMY LEVEL	MISSION DURATION	NUMBER OF FLIGHTS	PROGRAM DURATION	PROGRAM PHASING	RENDEZVOUS & DOCKING	SPIN-UP
MISSION PLANNING (320-11/12-01)							
o FLIGHT PLAN	N.A.	INCREASES	MULTIPLE	N.A.	N.A.	INCREASES	M.D.
o MALFUNCTION ANALYSIS	INCREASES	N.A.	N.A.	MULTIPLE	INCREASES	INCREASES	INCREASES
o ABORT PROFILES	INCREASES	N.A.	MULTIPLE	N.A.	INCREASES	INCREASES	INCREASES
o MISSION RULES	N.A.	N.A.	N.A.	MULTIPLE	INCREASES	INCREASES	INCREASES
o COMMAND HANDBOOK	DECREASES	N.A.	N.A.	N.A.	INCREASES	INCREASES	INCREASES
o PROCEDURES AND CHECKLISTS	INCREASES	N.A.	N.A.	MULTIPLE	INCREASES	INCREASES	INCREASES
o INSTRUMENTATION LIST	N.A.	N.A.	N.A.	MULTIPLE	INCREASES	INCREASES	INCREASES
o OPERATIONAL DATA BOOK	INCREASES	N.A.	N.A.	N.A.	INCREASES	INCREASES	INCREASES
o SYSTEM SCHEMATICS	INCREASES	N.A.	N.A.	N.A.	INCREASES	INCREASES	INCREASES
o INTERFACE DRAWINGS	INCREASES	N.A.	N.A.	MULTIPLE	INCREASES	INCREASES	INCREASES
o SCHEDULES	N.A.	N.A.	N.A.	MULTIPLE	N.A.	N.A.	N.A.
FLIGHT CONTROL (320-11/12/02)							
o CONTROL REQUIREMENTS	DECREASES	INCREASES	MULTIPLE	N.A.	N.A.	INCREASES	INCREASES
o CONTROL ANALYSIS	N.A.	INCREASES	MULTIPLE	N.A.	N.A.	INCREASES	INCREASES
o PLANNING	DECREASES	N.A.	N.A.	N.A.	INCREASES	INCREASES	N.A.
o FLIGHT CONTROL	DECREASES	INCREASES	MULTIPLE	N.A.	N.A.	N.A.	N.A.
o ANALYSIS ANOMALIES	DECREASES	INCREASES	MULTIPLE	N.A.	N.A.	N.A.	N.A.
o CHECKOUT	DECREASES	N.A.	MULTIPLE	N.A.	N.A.	N.A.	N.A.
o ACTIVATION	DECREASES	N.A.	MULTIPLE	N.A.	N.A.	N.A.	N.A.
FLIGHT EVALUATION (320-11/12-03)							
o DATA REDUCTION	N.A.	INCREASES	MULTIPLE	N.A.	N.A.	N.A.	N.A.
o DATA ANALYSIS	N.A.	INCREASES	MULTIPLE	N.A.	N.A.	N.A.	N.A.
o RESOLVE ANOMALIES	N.A.	INCREASES	MULTIPLE	N.A.	N.A.	N.A.	N.A.
o REPORT	N.A.	INCREASES	MULTIPLE	N.A.	N.A.	N.A.	N.A.
FLIGHT SUPPORT SOFTWARE (320-11/12-04)							
o PLANNING	N.A.	N.A.	N.A.	N.A.	N.A.	INCREASES	N.A.
o FLIGHT CONTROL	DECREASES	N.A.	N.A.	N.A.	N.A.	INCREASES	INCREASES
o SIMULATIONS	DECREASES	INCREASES	N.A.	N.A.	N.A.	INCREASES	INCREASES
o FLIGHT SUPPORT	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
o CONTROL SUPPORT	INCREASES	N.A.	N.A.	N.A.	N.A.	INCREASES	INCREASES
o FLIGHT EVALUATION	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

The Operations tasks were further analyzed in terms of actual people and skills required. It was determined that a minimum operations crew (one for each of three shifts) was required for flight control of only one Tug flight. These crews are capable of handling a significant number of flights per month; a greater number than sometimes required by the mission model. Even though these crews are utilized to perform the mission planning, flight evaluation and flight support software tasks in addition to their flight control requirements, there is sometimes an excess of manhours available. In order to allow for this, the manhours available from the minimum crews are incorporated into the computer program as minimum for the 32C area. When the actual manhours requirements are calculated, if the total does not exceed the minimum, then the minimum is used and the unused manhours are shown. This minimum crew is required for both NASA and DOD.

Option 3 is a phased program consisting of two distinct configurations. The initial configuration is operational for four years before the final configuration is introduced and overlaps the final configuration operational period by 4 years for NASA Tugs and 3 years for DOD Tugs. The final configuration has a seven year operational life. The initial configuration has a level IV autonomy, a 3 day mission duration and no rendezvous, docking or spin-up capability. The final configuration has a level III autonomy, a 6 day mission duration and has rendezvous, docking and spin-up capabilities. The appropriate factors including proportional values for the years during the overlap of the two configurations, the number of flights and the mission times were input into the computer program. The results of the calculations are shown in Section 4.

The effect of DOD procurement of the Tug program on Option 3 was analyzed. This permitted operational mission flights of the final configuration two years earlier and changed the numbers of flights per year and the mission times. The computer program inputs were revised to reflect these changes and the results are shown in the following pages.

: OPTION = 3 DOD BUY

YEAR = 1980

NUMBER OF FLIGHTS = 3,0

AUTONOMY LEVEL = 3,0

NASA MISSION

MISSION DURATION = 43,0

LAUNCH FROM WTR = 0,0

LAUNCH FROM ETR = 3,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	17619,1	190,0	409990,4
FLIGHT CONTROL	=	101956,3	221,3	2123870,4
FLIGHT EVALUATION	=	5226,5	68,6	130919,7
FLIGHT SOFTWARE	=	12480,0	49,0	330753,4
UNUSED MANHOURS	=	92453,0	0,0	1849059,2
TOTAL OPS, HOURS	=	124800,0	489,6	
TOTAL OPS, COSTS	=	2808000,0	127533,9	2995533,9

OPERATIONS PER/FLT COSTS = 998511.3

OPTION = 3

YEAR = 1981

NUMBER OF FLIGHTS = 14,0

AUTONOMY LEVEL = 3,0

NASA MISSION

MISSION DURATION = 41,1

LAUNCH FROM WTR = 0,0

LAUNCH FROM ETR = 14,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	26019,2	236,0	611466,7
FLIGHT CONTROL	=	74718,4	1007.4	1880210,4
FLIGHT EVALUATION	=	24066,4	316,7	602609,7
FLIGHT SOFTWARE	=	12480,0	173,6	378476,3
UNUSED MANHOURS	=	31220,3	0,0	624406,7
TOTAL OPS, HOURS	=	124800,0	1735,7	
TOTAL OPS, COSTS	=	2808000,0	664763,1	3472763,1

OPERATIONS PER/FLT COSTS = 248054,5

OPTION = 3

YEAR = 1982

NUMBER OF FLIGHTS = 8,0

AUTONOMY LEVEL = 3,0

NASA MISSION

MISSION DURATION = 39,2

LAUNCH FROM WTR = 0,0

LAUNCH FROM ETR = 8,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	23971,6	197,9	555081,1
FLIGHT CONTROL	=	87266,7	472,8	1926409,2
FLIGHT EVALUATION	=	13561,7	178,4	339577,6
FLIGHT SOFTWARE	=	12480,0	94,0	348118,7
UNUSED MANHOURS	=	65569,1	0,0	1311381,9
TOTAL OPS, HOURS	=	124800,0	943,0	
TOTAL OPS, COSTS	=	2808000,0	361186,5	3169186,5

OPERATIONS PER/FLT COSTS = 396148,3

```
OPTION                 =    3
YEAR                   = 1983
NUMBER  OF  FLIGHTS    = 15,0
AUTONOMY  LEVEL        =  3,0
NASA  MISSION
MISSION  DURATION      = 37,1
LAUNCH  FROM  WTR      =  4,0
LAUNCH  FROM  ETR      = 15,0
FLIGHT  OPERATIONS  RECURRING  COSTS (ANNUAL)
                          MANHOURS     COMPUTER  HOURS       COSTS
MISSION  PLANNING     =    28040,2              249,1     656203,6
FLIGHT  CONTROL       =    71726,5              946,9    1797176,1
FLIGHT  EVALUATION    =    25033,3              329,4     626821,1
FLIGHT  SOFTWARE      =    12480,0              169,5     378911,2
UNUSED  MANHOURS      =    29336,4                0,0     586767,6
TOTAL  OPS,  HOURS    =   124800,0             1694,8
TOTAL  OPS,  COSTS    =  2808000,0           649112,0    3457112,0
OPERATIONS PER/FLT COSTS  =     230474,1
```

OPTION = 3

YEAR = 1984

NUMBER OF FLIGHTS = 26,0

AUTONOMY LEVEL = 3,0

NASA MISSION

MISSION DURATION = 39,0

LAUNCH FROM WTR = 4,0

LAUNCH FROM ETR = 22,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	43006,7	375,4	1003913,2
FLIGHT CONTROL	=	78226,1	1481,2	2131810,5
FLIGHT EVALUATION	=	44021,6	579,1	1102221,0
FLIGHT SOFTWARE	=	16525,4	270,0	516786,7
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS, HOURS	=	165254,4	2706,3	
TOTAL OPS, COSTS	=	3718224,6	1036506,0	4754731,4

OPERATIONS PER/FLT COSTS = 182874,3

OPTION = 3

YEAR = 1985

NUMBER OF FLIGHTS = 28.0

AUTONOMY LEVEL = 3.0

NASA MISSION

MISSION DURATION = 39.0

LAUNCH FROM WTR = 6.0

LAUNCH FROM ETR = 22.0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	47214.9	405.7	1099685.6
FLIGHT CONTROL	=	78279.7	1412.9	2106729.0
FLIGHT EVALUATION	=	47031.7	623.6	1179484.1
FLIGHT SOFTWARE	=	17292.6	271.4	535246.1
UNUSED MANHOURS	=	0.0	0.0	0.0
TOTAL OPS, HOURS	=	172526.3	2713.6	
TOTAL OPS, COSTS	=	3881842.2	1039302.6	4921144.8

OPERATIONS PER/FLT COSTS = 175755.2

OPTION = 3

YEAR = 1986

NUMBER OF FLIGHTS = 24,0

AUTONOMY LEVEL = 3,0

NASA MISSION

MISSION DURATION = 36,7

LAUNCH FROM WTR = 4,0

LAUNCH FROM ETR = 20,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	41104,4	353,9	957635,8
FLIGHT CONTROL	=	68640.3	1276.3	1862389.0
FLIGHT EVALUATION	=	42161,7	525,4	1044475,6
FLIGHT SOFTWARE	=	15190,6	239,7	471585,2
UNUSED MANHOURS	=	0,0	0.0	0,0
TOTAL OPS. HOURS	=	151906,4	2397,4	
TOTAL OPS. COSTS	=	3417894,4	918191,1	4336085,5

OPERATIONS PER/FLT COSTS = 180670.2

: OPTION = 3

YEAR = 1987

NUMBER OF FLIGHTS = 24,0

AUTONOMY LEVEL = 3,0

NASA MISSION

MISSION DURATION = 45,8

LAUNCH FROM WTR = 6,0

LAUNCH FROM ETR = 18,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	41828,6	36[illegible]	974664,3
FLIGHT CONTROL	=	74169,7	1434,9	2032978,5
FLIGHT EVALUATION	=	45052,2	561,5	1116080,5
FLIGHT SOFTWARE	=	16105,0	261,9	502927,7
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS, HOURS	=	161050,4	2618,8	
TOTAL OPS, COSTS	=	3623634,9	1003016,0	4626650,9

OPERATIONS PER/FLT COSTS = 192777,1

OPTION	=	3		
YEAR	=	1988		
NUMBER OF FLIGHTS	=	19,0		
AUTONOMY LEVEL	=	3,0		
NASA MISSION				
MISSION DURATION	=	48,6		
LAUNCH FROM WTR	=	4,0		
LAUNCH FROM ETR	=	15,0		
FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)				
		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	39336,7	326,0	911813,8
FLIGHT CONTROL	=	56758,8	1050,9	1537657,1
FLIGHT EVALUATION	=	42917,5	453,3	1031947,8
FLIGHT SOFTWARE	=	13961,3	203,4	425439,0
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS, HOURS	=	139012,9	2034,1	
TOTAL OPS, COSTS	=	3127790,7	779367,0	3906857,6
OPERATIONS PER/FLT COSTS	=	205624,1		

OPTION	=	3		
YEAR	=	1989		
NUMBER OF FLIGHTS	=	25,0		
AUTONOMY LEVEL	=	3,0		
NASA MISSION				
MISSION DURATION	=	35,4		
LAUNCH FROM WTR	=	5,0		
LAUNCH FROM ETR	=	20,0		

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	43277,4	365,3	1005475,2
FLIGHT CONTROL	=	65120,8	1165,3	1748721,1
FLIGHT EVALUATION	=	42298,4	542,0	1053541,5
FLIGHT SOFTWARE	=	15069,7	230,3	464941,6
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS, HOURS	=	150696,6	2302,9	
TOTAL OPS, COSTS	=	3390674,4	882000,0	4272674,3

OPERATIONS PER/FLT COSTS = 170907,0

OPTION	=	3
YEAR	=	1990
NUMBER OF FLIGHTS	=	22,0
AUTONOMY LEVEL	=	3,0
NASA MISSION		
MISSION DURATION	=	37,5
LAUNCH FROM WTR	=	4,0
LAUNCH FROM ETR	=	18,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	41486,2	346,1	963101,3
FLIGHT CONTROL	=	59844,0	1060,7	1603115,0
FLIGHT EVALUATION	=	41299,0	484,6	1011563,5
FLIGHT SOFTWARE	=	14263,1	210,4	437150,9
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS, HOURS	=	142631,2	2103,7	
TOTAL OPS, COSTS	=	3209202,4	805728,0	4014930,7

OPERATIONS PER/FLT COSTS = 182496,8

OPTION = 3 - DOD BUY

TOTAL PROGRAM COSTS

NUMBER OF FLIGHTS =208,0

AUTONOMY LEVEL = 3,0

NASA MISSION

LAUNCH FROM WTR = 37,0

LAUNCH FROM ETR =175,0

FLIGHT OPERATIONS RECURRING COSTS (NASA ONLY)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	392895,0	3370,9	9149023,9
FLIGHT CONTROL	=	816707,3	11532,4	20751066,2
FLIGHT EVALUATION	=	372672,0	4662,7	9239242,0
FLIGHT SOFTWARE	=	158227,8	2174,0	4768336,7
UNUSED MANHOURS	=	218580,8	0,0	4371619,4
TOTAL OPS. HOURS	=	1582278,4	21740,0	
TOTAL OPS, COSTS	=	35601263,6	8326407,2	43927670,7

OPERATIONS PER/FLT COSTS = 211190,7

FLIGHT OPERATIONS NON-RECURRING COSTS (TOTAL PROGRAM FOR BOTH DOD & NASA)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	478264,6	2008,0	11543527,2
FLIGHT CONTROL	=	52263.9	0,0	1175938.2
FLIGHT EVALUATION	=	0,0	0,0	0,0
FLIGHT SOFTWARE	=	178005.2	3122.3	5200963.6
TOTAL DDT E HOURS	=	709133.7	5130.3	
TOTAL DDT E COSTS	=	15955509.0	1964904.9	17920429.0

OPTION	=	3 DOD BUY
YEAR	=	1981
NUMBER OF FLIGHTS	=	7,0
AUTONOMY LEVEL	=	3,0
DOD MISSION		
MISSION DURATION	=	39,6
LAUNCH FROM WTR	=	0,0
LAUNCH FROM ETR	=	7,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	[illegible]	181,8	481789,6
FLIGHT CONTROL	=	92289,8	493,8	2034916,9
FLIGHT EVALUATION	=	11901,6	156,6	298009,2
FLIGHT SOFTWARE	=	[illegible]	92,5	347412,9
UNUSED MANHOURS	=	70876,7	0,0	1417534,3
TOTAL OPS, HOURS	=	124800,0	924,6	
TOTAL OPS, COSTS	=	[illegible]	354128,6	3162128,6

OPERATIONS PER/FLT COSTS = 451732,7

: OPTION = 3

YEAR = 1982

NUMBER OF FLIGHTS = 10,0

AUTONOMY LEVEL = 3,0

DOD MISSION

MISSION DURATION = 39,8

LAUNCH FROM WTR = 0,0

LAUNCH FROM ETR = 10,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	22895,5	205,6	536639,6
FLIGHT CONTROL	=	84877,2	707,3	1968440,8
FLIGHT EVALUATION	=	17327,3	224,0	426355,2
FLIGHT SOFTWARE	=	12480,0	126,3	360381,7
UNUSED MANHOURS	=	54223,1	0,0	1084462,0
TOTAL OPS, HOURS	=	124800,0	1263,2	
TOTAL OPS, COSTS	=	2808000,0	483817,4	3291817,4

OPERATIONS PER/FLT COSTS = 329181,7

OPTION = 3

YEAR = 1983

NUMBER OF FLIGHTS = 15,0

AUTONOMY LEVEL = 3,0

DOD MISSION

MISSION DURATION = 42,9

LAUNCH FROM WTR = 4,0

LAUNCH FROM ETR = 11,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	28365,0	251,7	657704,4
FLIGHT CONTROL	=	70610,2	1053,6	1815717,3
FLIGHT EVALUATION	=	26123,9	343,7	654127,8
FLIGHT SOFTWARE	=	12486,0	183,2	382172,2
UNUSED MANHOURS	=	24681,5	0,0	493629,6
TOTAL OPS, HOURS	=	124800,0	1832,2	
TOTAL OPS, COSTS	=	2808300,0	701721,6	3509721,6

OPERATIONS PER/FLT COSTS = 233981,4

OPTION = 3

YEAR = 1984

NUMBER OF FLIGHTS = 18,0

AUTONOMY LEVEL = 3,0

DOD -MISSION

MISSION DURATION = 40,6

LAUNCH FROM WTR = 1,0

LAUNCH FROM ETR = 17,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	35876,8	308,2	835568,5
FLIGHT CONTROL	=	58594,1	964,1	1531115,3
FLIGHT EVALUATION	=	30829,7	405,7	771959,1
FLIGHT SOFTWARE	=	12480,6	186,4	383404,8
UNUSED MANHOURS	=	9540,4	0,0	190808,3
TOTAL OPS, HOURS	=	124800,0	1864,4	
TOTAL OPS, COSTS	=	2808000,0	714047,7	3522047,7

OPERATIONS PER/FLT COSTS = 195669,3

:OPTION = 3

YEAR = 1985

NUMBER OF FLIGHTS = 13,0

AUTONOMY LEVEL = 3,0

DOD MISSION

MISSION DURATION = 48,5

LAUNCH FROM WTR = 2,0

LAUNCH FROM ETR = 11,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	31244,5	260,8	724783,3
FLIGHT CONTROL	=	70002,5	765,1	1693095,4
FLIGHT EVALUATION	=	23553,2	309,9	589760,4
FLIGHT SOFTWARE	=	12480,4	149,4	368848,8
UNUSED MANHOURS	=	32968,1	0,0	657362,7
TOTAL OPS, HOURS	=	124800,8	1484,3	
TOTAL OPS, COSTS	=	2808508,2	568487,9	3376487,9

OPERATIONS PER/FLT COSTS = 259729,8

OPTION	= 3			
YEAR	= 1986			
NUMBER OF FLIGHTS	= 17,0			
AUTONOMY LEVEL	= 3,0			
DOD MISSION				
MISSION DURATION	= 36,4			
LAUNCH FROM WTR	= 5,0			
LAUNCH FROM ETR	= 12,0			

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	34446,7	297,9	803026,4
FLIGHT CONTROL	=	62132,5	854,4	1569865,8
FLIGHT EVALUATION	=	28221,9	371,3	706662,2
FLIGHT SOFTWARE	=	12483,0	169,3	376839,4
UNUSED MANHOURS	=	17436,4	0,0	348727,1
TOTAL OPS, HOURS	=	124800,0	1692,9	
TOTAL OPS, COSTS	=	2808000,0	648393,8	3456393,8

OPERATIONS PER/FLT COSTS = 203317,3

OPTION = 3

YEAR = 1987

NUMBER OF FLIGHTS = 16,0

AUTONOMY LEVEL = 3,0

DOD MISSION

MISSION DURATION = 47,3

LAUNCH FROM WTR = 2,0

LAUNCH FROM ETR = 14,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	36251,2	294,4	838538,6
FLIGHT CONTROL	=	47418,4	872,1	1282392,3
FLIGHT EVALUATION	=	40733,6	378,3	959546,2
FLIGHT SOFTWARE	=	12443,3	171,9	376831,7
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS, HOURS	=	124403,1	1718,6	
TOTAL OPS, COSTS	=	2799370,6	658238,2	3457308,8

OPERATIONS PER/FLT COSTS = 216081,8

OPTION = 3

YEAR = 1988

NUMBER OF FLIGHTS = 18,0

AUTONOMY LEVEL = 3,0

DOD MISSION

MISSION DURATION = 39,1

LAUNCH FROM WTR = 2,0

LAUNCH FROM ETR = 16,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	38862,2	314,6	881738,6
FLIGHT CONTROL	=	50331,1	888,9	1347077,3
FLIGHT EVALUATION	=	39533,5	401,2	944330,0
FLIGHT SOFTWARE	=	12792,7	178,3	388107,0
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS, HOURS	=	127926,8	1783,0	
TOTAL OPS, COSTS	=	2878353,2	682899,7	3561252,9

OPERATIONS PER/FLT COSTS = 197847,4

OPTION = 3

YEAR = 1989

NUMBER OF FLIGHTS = 16,0

AUTONOMY LEVEL = 3,0

DOD MISSION

MISSION DURATION = 51,2

LAUNCH FROM WTR = 4,0

LAUNCH FROM ETR = 12,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	36229,6	295,9	837904,5
FLIGHT CONTROL	=	48483,7	910,3	1318312,8
FLIGHT EVALUATION	=	41841,9	388,6	985653,8
FLIGHT SOFTWARE	=	12555,4	177,2	384250,7
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS, HOURS	=	126554,2	1771,9	
TOTAL OPS, COSTS	=	2847468,8	678653,1	3526121,9

OPERATIONS PER/FLT COSTS = 220382,6

OPTION = 3

YEAR = 1990

NUMBER OF FLIGHTS = 18,0

AUTONOMY LEVEL = 3,0

DOD MISSION

MISSION DURATION = 40,7

LAUNCH FROM WTR = 1,0

LAUNCH FROM ETR = 17,0

FLIGHT OPERATIONS RECURRING COSTS (ANNUAL)

		MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING	=	38339,6	314,3	881153,6
FLIGHT CONTROL	=	50802,3	906,4	1363214,6
FLIGHT EVALUATION	=	40001,6	406,0	955510,6
FLIGHT SOFTWARE	=	12384,3	180,7	391331,9
UNUSED MANHOURS	=	0,0	0,0	0,0
TOTAL OPS, HOURS	=	128843,4	1807,4	
TOTAL OPS, COSTS	=	2898977,2	692233,5	3591210,7

OPERATIONS PER/FLT COSTS = 199511,7

OPTION = 3 - DOD BUY

~~TOTAL PROGRAM COSTS~~

NUMBER OF FLIGHTS =148.0

AUTONOMY LEVEL = 3.0

~~DOD MISSION~~

LAUNCH FROM WTR = 21.0

LAUNCH FROM ETR =127.0

~~FLIGHT OPERATIONS RECURRING COSTS~~ (DOD ONLY)

	MANHOURS	COMPUTER HOURS	COSTS
MISSION PLANNING =	321718.2	2727.1	7478847.3
~~FLIGHT CONTROL =~~	~~635341.2~~	~~8416.0~~	~~15924148.5~~
FLIGHT EVALUATION =	299768.2	3385.3	7291914.6
FLIGHT SOFTWARE =	125652.8	1614.3	3759581.0
~~UNUSED MANHOURS =~~	~~209626.2~~	~~0.0~~	~~4192524.0~~
TOTAL OPS. HOURS =	1256527.5	16142.6	
TOTAL OPS. COSTS =	28271867.0	6182621.6	34454491.4

~~OPERATIONS PER/FLT COSTS = 232800.6~~

FLIGHT OPERATIONS NON-RECURRING COSTS (TOTAL PROGRAM FOR BOTH DOD & NASA)

	MANHOURS	COMPUTER HOURS	COSTS
~~MISSION PLANNING =~~	~~478364.6~~	~~2008.0~~	~~11543527.2~~
FLIGHT CONTROL =	52263.9	0.0	1175938.2
FLIGHT EVALUATION =	0.0	0.0	0.0
~~FLIGHT SOFTWARE~~ =	178005.2	3122.3	5200963.6
TOTAL DDT E HOURS =	709133.7	5130.3	
TOTAL DDT E COSTS =	15955509.0	1964904.9	17920429.0

WBS 32A-11/12 FLIGHT OPERATIONS

4.1 WBS 32A-11/12-01 Mission Planning

32A-11/12-01-01 Perform Malfunction Analyses and Prepare Contingency Profiles

Description: Includes identification of possible failure modes and effects and develops alternate flight profiles to accomplish mission objectives.

Rationale: This is a one time effort for each configuration and increases according to the configuration complexity. Autonomy level, rendezvous and docking, and payload spin-up are used to measure this complexity.

Ref Config: During the 18 months preceding IOC, this task requires 5 men for the first 6 month period, 4 men for the second and 1 man for the third. The task also requires 260 computer hours.

Equation: (10,400 MH + 344 CH) AIxRDxSPxPP

WBS 32A-11/12 FLIGHT OPERATIONS

WBS 32A-11/12-01 Mission Planning

32A-11/12-01-02 Prepare Abort Profiles

Description: Identify the abort modes for the Tug and the Tug/Shuttle operations and prepare abort profiles for all abort modes.

Rationale: This item requires an initial effort for each type of mission. This effort increases according to configuration complexity and is measured by autonomy level, rendezvous and docking, and payload spin-up.

Ref Config: The initial effort is estimated to require 1 man for the 30 months preceding IOC plus 68 Computer hours.

Equation: (5200 MH + 68 CH) AIxRDxSPxPP

32A-11/12-01-03 Develop Flight Mission Rules and Supporting Data

Description: Analyze mission objectives in context with flight hardware performance capabilities and limitations to identify all necessary guidelines and constraints for mission accomplishment. List all these rules in a document.

Rationale: This is a one time effort which increases with retrieval and/or spin-up capability addition.

Ref Config: For the 30 months preceding IOC this task requires 10 men for the first 12 months and 20 men for the next 18 months plus 260 computer hours.

Equation: (83,200 MH + 344 CH) RDxSPxPP

WBS 32A-11/12 FLIGHT OPERATIONS

WBS 32A-11/12-01 Mission Planning

32A-11/12-01-04 Prepare Command Handbook

Description: Analyze on orbit functions to determine necessary commands, examine communication hardware to determine command mechanization and prepare a handbook containing all the information required to accomplish command control of the Tug.

Rationale: This is primarily a one time effort which decreases with increasing levels of autonomy and increases with retrieval and/or spin-up capability.

Ref Config: This item requires 5 men for the 12 months preceding IOC plus 260 computer hours.

Equation: (10,400 MH + 344 CH) ADxRDxSPxPP

32A-11/12-01-05 Prepare Systems Procedures and Checklists

Description: Analyze systems, subsystems, and interfaces to determine operational and checkout sequences. Transform these data into operating procedures and checklists for use by missions operations personnel.

Rationale: This is largely a one time effort which increases with configuration complexity as measured by autonomy level, retrieval, and spin-up capability.

Ref Config: This task requires 10 men for the 12 months preceding IOC.

Equation: (20,800 MH) AIxRDxSPxPP

482

WBS 32A-11/12 FLIGHT OPERATIONS

WBS 32A-11/12-01 Mission Planning

32A-11/12-01-06 Prepare Flight Instrumentation List

Description: Analyze instrumentation system capabilities and establish a list of all the parameters to be instrumented showing the type, location, sampling rate, coding, range, etc.

Rationale: This consists of an initial effort which increases with retrieval and spin-up capabilities.

Ref Config: This task requires 3 men for the 12 months period beginning 3 years prior to IOC.

Equation: (6240 MH) RDxSPxPP

32A-11/12-01-07 Prepare Flight Control Operational Data Handbook

Description: Assembly detail technical information on all components and prepare descriptions, performance charts and other pertinent data in book form.

Rationale: This is a one time effort which increases with configuration complexity and; therefore, increasing autonomy level, retrieval, and spin-up.

Ref Config: During the 24 months preceding IOC this task requires 6 men for the first 12 months and 2 men for the second 12 months.

Equation: (16,640 MH) AIxRDxSPxPP

32A-11/12-01-08 Prepare System Schematics including Vehicle Systems Handbook

Description: Includes preparation of schematic drawings for all Tug vehicle systems.

Rationale: This is a one time effort which increases with configuration complexity and is measured by increasing autonomy level, retrieval, and spin-up.

Ref Config: This task requires 5 men for the 12 months period beginning 30 months prior to IOC.

Equation: (10,400 MH) AIxRDxSPxPP

WBS 32A-11/12 FLIGHT OPERATIONS

WBS 32A-11/12-01 Mission Planning

32A-11/12-01-09 Prepare Interface Drawings

Description: Includes preparation of drawings to define both the internal interfaces between systems and the external interfaces between the Tug and other elements of the STS.

Rationale: This consists of an initial effort which increases with configuration complexity as measured by autonomy level, retrieval and spin-up.

Ref Config: During the 30 months preceding IOC this task requires 7 men for the first 12 months and 2 men for the next 18 months.

Equation: (20,800 MH) AIxRDxSPxPP

32A-11/12-01-10 Plan Launch Schedules

Description: Develop a long range launch schedule to efficiently accomplish the payload mission model considering payload requirements, Tug performance capabilities, fleet size, turnaround times, etc.

Rationale: This consists of an initial effort which is constant for all missions and configurations.

Ref Config: This task requires 3 men for the 12 months preceding IOC plus 43 computer hours.

Equation: (6240 MH + 43 CH)

WBS 32A-11/12 FLIGHT OPERATIONS

4.2 WBS 32A-11/12-02 Flight Control

32A-11/12-02-01 Perform Operations Planning

Description: The overall planning and coordination of the flight operations effort including determination of manpower, display console, computer, software, training and facility requirements for the Mission Control Center.

Rationale: This is a one time effort that decreases with increasing level of autonomy and increases with retrieval capability.

Ref Config: This task requires 10 men for the 18 months preceding IOC.

Equation: (31,200 MH) ADxRDxPP

485

4.3 WBS 32A-11/12-04 Flight Support Software

32A-11/12-04-01 Develop Computer Program for Mission Planning

Description: Development of a computer program to be used for determining mission trajectories and related mission planning functions such as ground communication opportunities.

Rationale: This is a one time effort essentially the same for all configurations and missions but increases for retrieval capability.

Ref Config: Requires 6 men for 1 year beginning 42 months prior to IOC plus 203 computer hours.

Equation: (12,480 MH + 407 CH) RD

32A-11/12-04-02 Develop Computer for Flight Control

Description: Development of a computer program to be used for determining vehicle control requirements for satisfying the desired trajectory, performing error analyses, and generating guidance and control constants.

Rationale: This is a one time effort that decreases with autonomy level and increases with retrieval and spin-up.

Ref Config: Requires 6 men for 2 years beginning 42 months prior to IOC plus 415 computer hours.

Equation: (24,960 MH + 830 CH) ADxRDxSP

32A-11/12-04-03 Develop Flight Operations Simulation

Description: Development of a software program for simulating the complete spectrum of flight operations to accomplish operations crew training and to evaluate and resolve inflight malfunctions. Also, to substantiate guidance and control constants.

Rationale: This is a one time effort that decreases with autonomy level and increases with mission duration, retrieval and spin-up.

Ref Config: During the 30 months prior to IOC this task requires 15 men for the first 18 months, 8 men for the next 6 months and 7 men for the last 6 months plus 1385 computer hours.

Equation: (62,400 MH + 1385 CH) ADxMDxRDxSP

486

WBS 32A-11/12 FLIGHT OPERATIONS

WBS 32A-11/12-04 Flight Support Software (Cont.)

32A-11/12-04-04 Prepare Shuttle Flight Support Software

Description: Covers the development of a general program to satisfy the software interface between the Tug and the Orbiter for activation, checkout, command, separation, docking, etc.

Rationale: This is a one time effort essentially the same for all configurations and missions.

Ref Config: Requires 3 men for 1 year beginning 24 months prior to IOC plus 104 computer hours.

Equation: (6240 MH + 208 CH)

32A-11/12-04-05 Develop Real Time Mission Software

Description: Development of software program for performing onboard functions of fault isolation, docking, stationkeeping, radar processing, mission planning, targeting, position/velocity update, and redundancy management, and evaluating mission success.

Rationale: This is a one time effort that increases with autonomy level, retrieval, and spin-up.

Ref Config: Requires 5 men for 2 years beginning 42 months prior to IOC plus 200 computer hours.

Equation: (41,600 MH + 746 CH) AIxRDxSP

32A-11/12-04-06 Develop Post Flight Evaluation Software

Description: Development of software program to provide for automatic comparison of post flight instrumentation data with nominal predictions plus tolerances for each parameter measured.

Rationale: This is a one time effort essentially the same for all configurations and missions.

Ref Config: Requires 6 men for 2 years beginning 30 months prior to IOC plus 415 computer hours.

Equation: 24,960 MH + 830 CH

4.4 Facilities (Non-Recurring)

The facilities required to perform orbital flight operations for both NASA at Houston, and DOD at Sunnyvale, were assumed for the Space Tug Study to be currently available at the respective mission control center. As a result of this assumption facilities costs for orbital flight operations are not included in the present cost model for the Space Tug.

WBS 32C-11/12 FLIGHT OPERATIONS

4.5 WBS 32C-11/12-01 Mission Planning

32C-11/12-01-01 Prepare Flight Plan

Description: Includes preparation of flight profiles, timelines, trajectories, mass histories, ground traces, etc., using the basic computer program for mission planning developed under Flight Support Software.

Rationale: This effort is required for each flight and increases with mission complexity including rendezvous and docking. Mission duration is used as the measure of complexity.

Ref Config: It was estimated to require three men for one month plus 6 hours of computer time to prepare each specific mission flight plan.

Equation: (519 MH + 6 CH) MDxNF + (104 MH + 1.2 CH) NFRD

32C-11/12-01-02 Perform Malfunction Analyses and Prepare Contingency Profiles

Description: Includes identification of possible failure modes and effects and develops alternate flight profiles to accomplish mission objectives.

Rationale: This is essentially a continuing effort for each configuration and increases according to the configuration complexity. Autonomy level, rendezvous and docking, and payload spin-up are used to measure this complexity.

Ref Config: This task requires a continuing level of 1 man for 11 years plus 344 computer hours.

Equation: (2,080 MH + 31.3 CH) AIxRDxSPxPD

WBS 32C-11/12-01 Mission Planning (Cont.)

32C-11/12-01-03 Prepare Abort Profiles

Description: Identify the abort modes for the Tug and the Tug/Shuttle operations and prepare abort profiles for all abort modes.

Rationale: This item requires an effort for each specific flight. This effort increases according to configuration complexity and is measured by autonomy level.

Ref Config: The effort is estimated to require 1 man month plus 2 computer hours for each flight.

Equation: (173 MH + 2 CH) AIxNF + (35 MH + 0.4 CH) AIxNFRDxSP

32C-11/12-01-04 Develop Flight Mission Rules and Supporting Data

Description: Analyzes mission objectives in context with flight hardware performance capabilities and limitations to identify all necessary guidelines and constraints for mission accomplishment. Lists all these rules in a document.

Rationale: This is an effort essentially the same for all configurations except those with rendezvous and docking which require an increased effort.

Ref Config: This task requires 2 men for 11 years plus 172 computer hours.

Equation: (4,160 MH + 172 CH) RDxPDxSP

WBS 32C-11/12 FLIGHT OPERATIONS

WBS 32C-11/12-01 Mission Planning (Cont.)

32C-11/12-01-05 Prepare Systems Procedures and Checklists

Description: Analyze systems, subsystems, and interfaces to determine operational and checkout sequences. Transform these data into operating procedures and checklists for use by missions operations personnel.

Rationale: This is a continuing effort which increases with configuration complexity as measured by autonomy level, rendezvous and docking, and spin-up capability.

Ref Config: This task requires 2 men for 11 years.

Equation: (4,160 MH) AIxRDxSPxPD

32C-11/12-01-06 Prepare Flight Instrumentation List

Description: Analyze instrumentation system capabilities and establish a list of all the parameters to be instrumented showing the type, location, sampling rate, coding, range, etc.

Rationale: This consists of a low level continuing effort and is essentially constant for all configurations except those with rendezvous and docking which require an increased effort.

Ref Config: This task requires 1 man for 13 years.

Equation: (2,080 MH) PDxRDxSP

WBS 32C-11/12 FLIGHT OPERATIONS

WBS 32C-11/12-01 Mission Planning (Cont.)

32C-11/12-01-07 Prepare Flight Control Operational Data Handbooks

Description: Assemble detail technical information on all components and prepare descriptions, performance charts and other pertinent data in book form.

Rationale: This is a continuing effort which increases with configuration complexity and, therefore, increasing autonomy level.

Ref Config: Requires 2 men for 11 years.

Equation: (4,160 MH) AIxRDxSPxPD

32C-11/12-01-08 Prepare Interface Drawings

Description: Includes preparation of drawings to define both the internal interfaces between systems and the external interfaces between the Tug and other elements of the STS.

Rationale: This consists of a continuing effort for the life of the program. It increases with configuration complexity as measured by autonomy level, retrieval, and spin-up.

Ref Config: Requires 2 men for 11 years.

Equation: (4,160 MH)AIxRDxSPxPD

WBS 32C-11/12 FLIGHT OPERATIONS

WBS 32C-11/12-01 Mission Planning (Cont.)

32C-11/12-01-09 Plan Launch Schedules

Description: Develop a long range launch schedule to efficiently accomplish the payload mission model considering payload requirements, Tug performance capabilities, fleet size, turnaround times, etc.

Rationale: This consists of a low level continuing effort for both ETR and WTR, which is constant for all missions and configurations.

Ref Config: Requires 1-1/2 men for 11 years for ETR and 1/2 man for 11 years for WTR.

Equation: (4,160 MH + 27.3 CH) PD

4.6 WBS 32C-11/12-02 Flight Control

32C-11/12-02-01 Analyze Flight Control Requirements for Ground Commands and Control Measurements

Description: Analyze the Flight Plan to determine what commands and control measurements are required, when ground access is available and from what stations commands will be transmitted and measurement data received.

Rationale: This effort is required for each flight and increases with increasing mission duration and retrieval and spin-up, and decreases with increasing level of autonomy.

Ref Config: Requires 2 men for 6 weeks plus 1 computer hour for each flight.

Equation: (480 MH + 1 CH) ADxMDxNF + (96 MH + 0.2 CH) NFRDxADxSP

32C-11/12-02-02 Run Computer Programs for Flight Control Including Guidance and Error Analysis

Description: The computer programs developed under Flight Support Software will be run for each specific flight to determine subsystem level data required for flight control functions such as power management data dump, altitude, pointing, and payload analysis. In addition, the flight tape will be generated and an error analysis of the flight tape will be performed.

Rationale: This effort is required for each flight and increases with mission duration and retrieval and spin-up.

Ref Config: Requires 4 men for 6 weeks plus 5 computer hours for each flight.

Equation: (960 MH + 5 CH) MDxNF + (192 MH + 1 CH) NFRDxSP

WBS 32C-11/12-02 Flight Control (Cont.)

32C-11/12-02-03 Perform Real (and Delayed) Time Flight Control

Description: Covers the flight controllers required to man the display consoles in the Mission Control Center for monitoring the vehicle, trajectory and engineering data, executing command control of all required on orbit functions, evaluating the accomplishment of primary mission objectives, determining the need for implementing alternate, contingency or abort flight modes and updating the flight plan.

Rationale: This effort is required per flight and starts one day before the launch and continues until Orbiter landing. It decreases with increasing level of autonomy and increases with mission duration.

Ref Config: Requires 6 men for 32 hours plus the mission duration plus use of a dedicated computer for same length of time for each flight.

Equation: [(16 + MT) 6 MH + (16 + MT) CH] ADxNF

32C-11/12-02-04 Analyze and Resolve Inflight Anomalies

Description: Covers the technical personnel required to support the flight controllers by analyzing flight data anomalies and determining their cause and effect.

Rationale: This effort is required for each flight from one day prior to launch until Orbiter landing and decreases with increasing level of autonomy and increases with mission duration.

Ref Config: Requires 14 men for 32 hours plus the mission duration for each flight.

Equation: [(16 + MT) 14 MH] ADxNF

WBS 32C-11/12-02 Flight Control (Cont.)

WBS 32C-11/12-02-05 Support Pre-Launch Checkout

Description: Covers the Mission Control Center support of the Tug pre-launch checkout to verify MCC/Tug interfaces and calibrations.

Rationale: This effort is required for each flight and decreases with increasing autonomy level.

Ref Config: Requires 20 men for 8 hours plus use of a dedicated computer for each flight.

Equation: (160 MH + 8 CH) ADxNF

WBS 32C-11/12-02-06 Support Launch and Tug Activation

Description: Covers the Mission Control Center support of the final launch checkout, ascent to orbit, and activation of the Tug by Orbiter crew.

Rationale: This effort is required for each flight and decreases with increasing level of autonomy.

Ref Config: Requires 20 men for 4 hours for launch support and 20 men for 4 hours for ascent and Tug activation plus a dedicated computer.

Equation: (160 MH + 8 CH) ADxNF

WBS 32C-11/12 FLIGHT OPERATIONS

4.7 WBS 32C-11/12-03 Flight Evaluation

32C-11/12-03-01 Perform Flight Data Reduction

Description: Transform raw flight TM and onboard recorded data into useful engineering form by means of computer.

Rationale: This task is required for each flight and increases with mission duration.

Ref Config: Requires 2 men for 2 weeks. Most of the effort is accomplished automatically requiring 10 computer hours per flight.

Equation: (160 MH + 10 CH) MDxNF

32C-11/12-03-02 Perform Post Flight Data Analysis

Description: This consists of a computer comparison of flight instrumented parametric data with nominal data to identify and isolate all out-of-tolerance conditions.

Rationale: This task is required for each flight and increases with mission duration.

Ref Config: Requires 2 men for 2 weeks plus 10 hours of computer time per flight. The bulk of the effort is automatically performed.

Equation: (160 MH + 10 CH) MDxNF

WBS 32C-11/12-03 Flight Evaluation (Cont.)

32C-11/12-03-03 Resolve Data Anomalies

Description: Analyze the flight data anomalies identified by the computer comparison and determine the cause and effect so that corrective action can be undertaken if necessary.

Rationale: This task is required for each flight and increases with mission duration.

Ref Config: Requires 8 men for 2 weeks plus 2 computer hours per flight.

Equation: (640 MH + 2 CH) MDxNF

32C-11/12-03-04 Prepare Flight Evaluation Report

Description: Prepare a final report of the flight data analysis which evaluates mission accomplishment and system performance and identifies problems encountered.

Rationale: Required for each flight and increases with mission duration.

Ref Config: Requires 3 men for 4 weeks for each flight.

Equation: (480 MH) MDxNF

WBS 32C-11/12 FLIGHT OPERATIONS

4.9 WBS 32C-11/12-04 FLIGHT SUPPORT SOFTWARE

32C-11/12-04-01 Mission Planning Software Changes

Description: Covers the changes to the mission planning software that result from requirement, design and program changes.

Rationale: This is a continuing effort for the life of the program.

Ref. Config: This task is estimated at 10% of the effort required for the mission planning tasks (32C-11/12-01).

Equation: Mission Planning MHx0.1 + Mission Planning CH x 0.1

32C-11/12-04-02 Flight Control Software Changes

Description: Covers the changes to the flight control software that result from requirement, design and program changes.

Rationale: This is a continuing effort for the life of the program.

Ref. Config: This task is estimated at 10% of the effort required for the flight control tasks. (32C-11/12-02).

Equation: Flight Control MHx0.1 + Flight Control CHx0.1

WBS 32C-11/12-04-03 Flight Evaluation Software Changes

Description: Covers the changes to the flight evaluation software that result from requirement, design and program changes.

Rationale: This is a continuing effort for the life of the program.

Ref. Config: This task is estimated at 10% of the effort required for the flight evaluation tasks (32C-11/12-03).

Equation: Flight Evaluation MHx0.1 + Flight Evaluation CHx0.1.

4.9 Network Operations Costs

Subsequent to the Concept Selection the COR directed that the network operations cost be removed from the flight operations cost estimates and that network utilization requirements be calculated instead. See Section 6.8 for the results of the network utilization requirements calculations.

5.0 SHUTTLE REQUIREMENTS

The operational requirements placed upon the Shuttle Orbiter are those concerned with (1) the structural and mechanical hardware used in support of Tug/payload deployment and retrieval operations, (2) the crew involvement in check out, monitoring, safing and passivation operations, deployment and retrieval manipulation, visual observations via closed-circuit TV, caution and warning displays and corrective system controls, and (3) the data management system interfaces, hardware and software, including computer support requirements by the Orbiter computer and the dedicated payload computer capability.

5.1 Deployment/Retrieval Timelines

The condensed operational timelines for Tug handling are shown in Table 5.1-1 (deployment of one or more payloads with a single Tug) and Table 5.1-2 (retrieval of a Tug alone or a Tug with payloads). The expanded timelines provided in Table 5.1-3 are representative for all deployment or retrieval mission and are based on the functiona flows presented in Figure 5.1-1.

5.2 Crew and Shuttle Functions

The crew functions are basically defined for a four-man crew, considering the Orbiter, Tug and Payload requirements. A review of these crew functions was conducted to consider four-man and smaller crew complements. The results are summarized in Figure 5.2-2 and the crew/Shuttle functions listed on the crew-size impact assessment charts. It was determined that a three-man crew can physically manage the dual functions of payload and Tug operations, plus the monitoring functions of the Orbiter, if the Orbiter has autopilot control and operates in a powered-down quiescent mode on-orbit. A common MSS/PSS console would better accommodate this option and would release the commander. However, a very desirable increase in operational flexibility, emergency response

Table 5.1-1

OPERATIONAL TIMELINE

DEPLOYMENT OF ONE OR MORE P/L WITH TUG

TUG LOCATION	OPERATION	TIME-MINUTES	CREW	MAN-MIN
BAY	PRE-DEPLOYMENT OPNS (ACTIVATE/CHECK/ OPEN DOORS)	32	1.5	48
BAY	DISENGAGE/DISCONNECT (ATTACHMENTS/LINES)	3	2	6
TILT TABLE	DEPLOY AND SEPARATE (ROTATE, ATTACH RMS, REMOVE, DISCONN. ELECT.)	10	3	30
RMS	MANIPULATE AND RELEASE	10	2	20
SHUTTLE PROXIMITY	MOVE SHUTTLE AWAY, ACTIVATE PROP./APS, COORBITAL CHECKS, HANDOFF CONTROL	33.5	2.5	84
SEPARATE	STOW MANIPULATOR	1.5	1	3
	TOTAL	90		191
				÷ 60
				= 3.2 MH

Table 5.1-2

OPERATIONAL TIMELINE

RETRIEVAL OF TUG OR TUG WITH PAYLOADS

TUG LOCATION	OPERATION	TIME-MINUTES	CREW	MAN-MIN
SEPARATE	ORBITER RENDEZVOUS			
	INITIAL TUG MANEUVERS	30	1	30
	STATIONKEEPING	52	1	52
	ORBITER MANEUVERS, SAFE TUG PROP, VENT/ DUMP TUG FLUIDS, VERIFY SAFE TUG	48	2	26
SHUTTLE PROXIMITY	ORBITER/TUG DOCKING			
	PREPARATION, TUG & SHUTTLE MANEUVERS, VERIFY SAFE TUG	23.5	2.5	59
RMS	MANIPULATOR OPERATIONS	22	2	44
RMS	PASSIVATE, VENT/DUMP FLUIDS, VERIFY SAFE TUG, RETRACT	65	2	130
TILT TABLE	MATE/LATCH, CONN. ELECT., STOW RMS, STOW TUG, CONN. LINES	14	2	28
BAY	PREP. TUG/PL FOR RETURN	17	2	39
	TOTAL	271.5		473
				÷ 60
				= 7.9 MH

4

Table 5.1-3

MISSION TIME HISTORY

DEPLOYMENT OF TWO PAYLOADS AND RETRIEVAL OF ONE

SYNCHRONOUS EQUATORIAL ORBIT

MISSION EVENT NO.	EVENT START TIME HR:MN:SC	EVENT DURATION HR:MN:SC	MISSION PHASES AND EVENTS
1	00:00:00	00:00:00	LIFTOFF
2	03:02:00	00:03:00	CIRCULARIZE IN 160 NM ORBIT (ORBITER)
3	03:05:00	08:00:00	PHASING COAST (ORBITER)
			PERFORM PRE-DEPLOY OPERATIONS
4	11:05:00	00:15:00	ACTIVATE & CHECK TUG SUBSYSTEMS EXCEPT PROPULSIVE (ORBITER)
5	11:05:00	00:05:00	ALIGN ORBITER IMU. UPDATE STATE VECTOR (ORBITER)
6	11:20:00	00:01:00	ORIENT FOR TUG DEPLOYMENT (ORBITER)
7	11:21:00	00:05:00	VERIFY PAYLOAD READINESS (GROUND/ORBITER)
8	11:21:00	00:03:00	ALIGN TUG IMU TO ORBITER IMU (ORBITER/TUG)
8A	11:21:00	00:03:00	OPEN PAYLOAD BAY DOORS
9	11:24:00	00:01:00	LOAD TUG COMPUTER WITH UPDATED STATE VECTOR (ORBITER/TUG)
10	11:25:00	00:01:00	DISCONNECT VENT LINE CONNECTOR (ORBITER)
11	11:26:00	00:01:00	DISENGAGE STOWAGE RETENTION DEVICES (ORBITER)
			DEPLOY AND SEPARATE TUG
12	11:27:00	00:05:00	DEPLOY TUG FROM CARGO BAY (ORBITER)
13	11:32:00	00:02:00	ACTIVATE/UNSTOW MANIPULATOR. ENGAGE TUG (ORBITER)
14	11:34:00	00:01:00	VERIFY PHYSICAL ATTACHMENT INTEGRITY (ORBITER)

Table 5.1-3

Sheet 2

MISSION EVENT NO.	EVENT START TIME HR:MN:SC	EVENT DURATION HR:MN:SC	MISSION PHASES AND EVENTS
15	11:35:00	00:01:00	DISCONNECT ELECTRICAL UMBILICALS (ORBITER)
16	11:36:00	00:01:00	DISCONNECT TUG FROM ORBITER ATTACHMENT (ORBITER)
17	11:37:00	00:08:00	MANIPULATE TUG TO RELEASE POSITION (ORBITER)
18	11:45:00	00:02:00	UNCOUPLE TUG FROM MANIPULATOR (ORBITER)
19	11:47:00	00:05:00	PERFORM ORBITER APS BURN. SEPARATE TO SAFE DISTANCE (ORBITER)
20	11:45:00	00:07:00	VISUALLY INSPECT TUG (ORBITER)
21	11:52:00	00:01:00	SEND ENABLE/ACTIVATE SIGNAL FOR TUG APS (ORBITER/TUG)
22	11:53:00	00:02:00	TUG ACTIVATE APS - VERIFY
23	11:55:00	00:00:30	ENABLE TUG ACTIVE ATTITUDE CONTROL (ORBITER)
24	11:55:30	00:00:30	TUG ACTIVATE ATTITUDE CONTROL
25	11:56:00	00:01:00	TRANSMIT ATTITUDE CONTROL READY SIGNALS
26	11:57:00	00:05:00	VERIFY TUG ATTITUDE CONTROL CAPABILITY (ORBITER)
27	12:02:00	00:02:00	ENABLE/ACTIVATE TUG MAIN PROPULSION SUBSYSTEM (ORBITER)
28	12:04:00	00:03:00	PERFORM POST-SEPARATION TUG SUBSYSTEM CHECKS (ORBITER)
29	12:07:00	00:06:00	TRANSMIT TUG SUBSYSTEMS CHECKOUT DATA
30	12:13:00	00:00:15	TRANSFER CONTROL TO TUG - MISSION ENABLE (ORBITER)
31	12:13:15	00:00:15	RECEIVE MISSION ENABLE - EXECUTE
32	12:13:30	00:01:30	RETRACT AND STOW MANIPULATOR (ORBITER)

Table 5.1-3

Sheet 3

MISSION EVENT NO.	EVENT START TIME HR:MN:SC	EVENT DURATION HR:MN:SC	MISSION PHASES AND EVENTS
181	126:04:55	00:05:00	MANEUVER TO REQUIRED ATTITUDE FOR ROI BURN
182	126:09:55	00:03:00	VERIFY SUBSYSTEM READINESS FOR ROI BURN
183	126:12:55	00:02:00	REPORT STATUS TO MISSION CONTROL
184	126:14:55	00:01:35	PERFORM ROI BURN (MAIN ENGINE)
185	126:16:30	00:02:00	REPORT STATUS TO MISSION CONTROL
186	126:18:30	26:00:00	PERFORM COAST OPERATIONS
187	126:18:30	26:30:00	STATIONKEEP
			PERFORM ORBITER RENDEZVOUS WITH TUG
188	152:18:30	00:05:00	ALIGN IMU. UPDATE STATE VECTOR (ORBITER)
189	152:23:30	00:10:00	ACQUIRE & LOCK-ON TO TUG (ORBITER)
190	152:33:30	00:03:00	ESTABLISH COMMUNICATION BETWEEN VEHICLES (ORBITER)
191	152:36:30	00:02:00	TRANSFER TUG FLIGHT CONTROL TO ORBITER. VERIFY (ORBITER/TUG)
192	152:33:30	00:05:00	RESPOND TO ORBITER COMMUNICATIONS
193	152:38:30	00:05:00	MANEUVER TUG TO PREFERRED RENDEZVOUS ATTITUDE (ORBITER/TUG)
194	152:43:30	00:55:00	STATIONKEEP, MAINTAIN ATTITUDE CONTROL
195	152:43:30	00:01:00	ACTIVATE TUG RENDEZVOUS AIDS (ORBITER/TUG)
196	152:44:30	00:03:00	CONFIGURE TUG FOR RENDEZVOUS (ORBITER/TUG)
197	152:47:30	00:00:30	TRANSMIT RENDEZVOUS READINESS SIGNAL
198	152:48:00	00:04:00	DETERMINE RANGE & RANGE RATE (ORBITER)

Table 5.1-3

Sheet 4

MISSION EVENT NO.	EVENT START TIME HR:MN:SC	EVENT DURATION HR:MN:SC	MISSION PHASES AND EVENTS
199	152:52:00	00:02:00	DETERMINE RENDEZVOUS INTERCEPT MANEUVERS (ORBITER)
200	152:54:00	00:03:00	COMPUTE TPI BURN PARAMETERS (ORBITER)
201	152:57:00	00:05:00	MANEUVER ORBITER TO REQUIRED ATTITUDE FOR TPI BURN (ORBITER)
202	153:02:00	00:03:00	VERIFY ORBITER READINESS FOR TPI BURN (ORBITER)
203	153:05:00	00:01:00	PERFORM TPI BURN (OMS ENGINES) (ORBITER)
204	153:06:00	00:03:00	PERFORM COURSE CORRECTION OPERATIONS (ORBITER)
205	153:09:00	00:01:00	COMMAND DEACTIVATION/SAFE TUG MAIN PROPULSION (ORBITER)
206	153:10:00	00:01:00	DEACTIVATE/SAFE MAIN PROPULSION
207	153:11:00	00:01:00	VERIFY COMPLETION OF MAIN PROPULSION SAFING (ORBITER/TUG)
208	153:12:00	00:04:00	DETERMINE RANGE & RANGE RATE (ORBITER)
209	153:16:00	00:03:00	COMPUTE TPF BURN PARAMETERS (ORBITER)
210	153:19:00	00:03:00	ORIENT ORBITER FOR INITIAL TPF BURN (ORBITER)
211	153:22:00	00:03:00	VERIFY ORBITER READINESS FOR TPF BURNS (ORBITER)
212	153:25:00	00:00:30	PERFORM TPF BURNS (OMS/APS ENGINES) (ORBITER)
213	153:25:30	00:03:00	VENT & DUMP EXCESS TUG FLUIDS (TUG/ORBITER)
214	153:25:30	00:03:00	VERIFY PAYLOAD SAFE FOR DOCKING (TUG/ORBITER)
			PERFORM ORBITER/TUG DOCKING & POST-DOCKING OPERATIONS (ORBITER/TUG)
215	153:28:30	00:04:00	READY CARGO BAY & MANIPULATOR FOR TUG RETRIEVAL (ORBITER)

Table 5.1-3

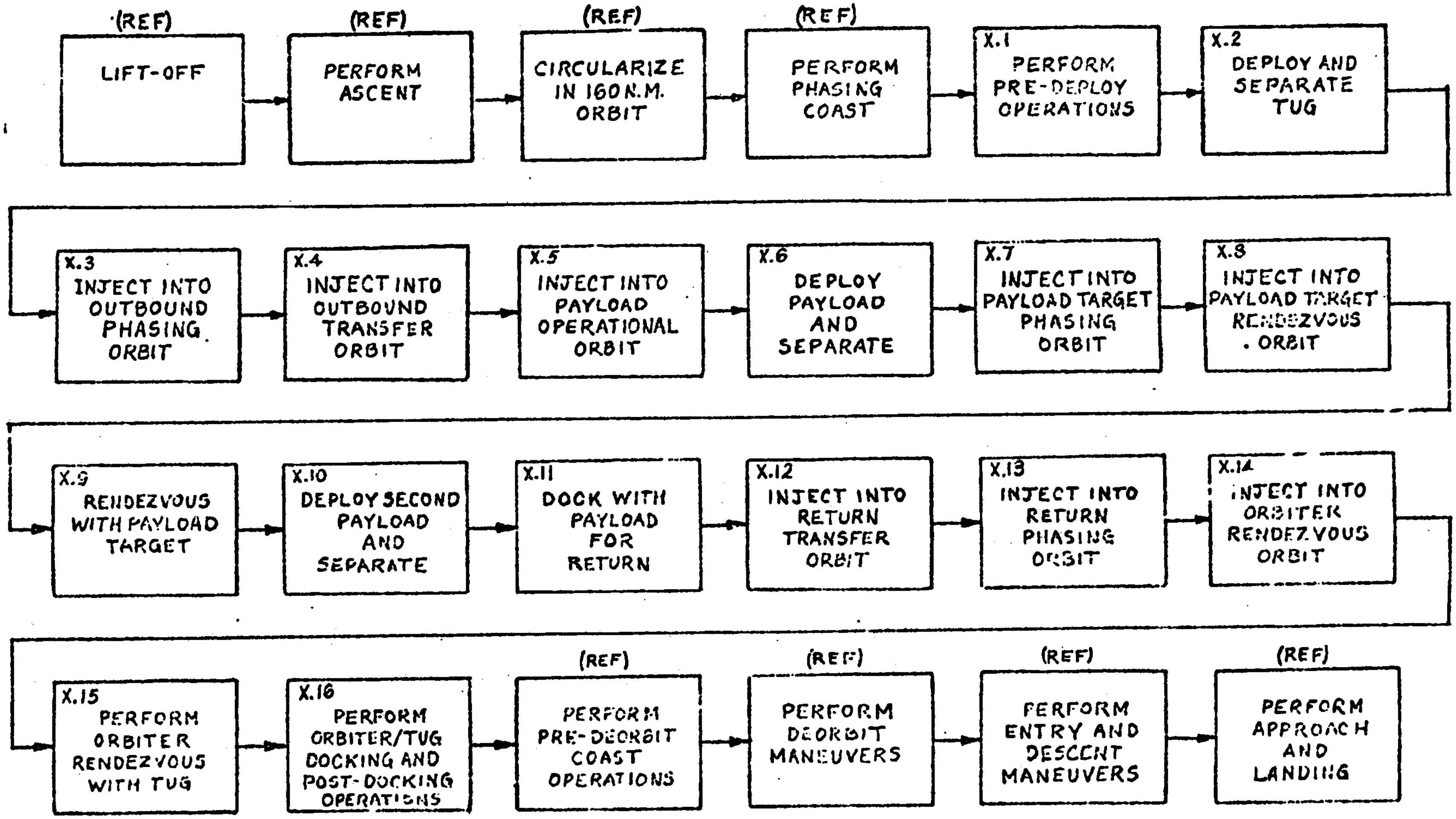
Sheet 5

MISSION EVENT NO.	EVENT START TIME HR:MN:SC	EVENT DURATION HR:MN:SC	MISSION PHASES AND EVENTS
216	153:28:30	00:00:30	COMMAND TUG TO PREFERRED DOCKING ATTITUDE (ORBITER)
217	153:29:00	00:03:00	MANEUVER TUG TO PREFERRED DOCKING ATTITUDE
218	153:28:30	00:04:00	VISUALLY INSPECT TUG (& PL) FOR DOCKING READINESS (ORBITER)
219	153:32:30	00:06:00	VERIFY ALL TUG SUBSYSTEMS (EXCEPT APS) SAFE FOR DOCKING (ORBITER/TUG)
220	153:32:30	00:06:00	MANEUVER TO FINAL DOCKING STATION (ORBITER)
221	153:38:30	00:15:00	ATTACH MANIPULATOR TO TUG (ORBITER)
222	153:53:30	00:02:00	VERIFY PHYSICAL ATTACHMENT INTEGRITY (ORBITER)
223	153:55:30	00:00:30	INHIBIT TUG APS JET FIRINGS (ORBITER/TUG)
224	153:55:30	00:00:30	COMMAND TUG RETRACTION/STOWAGE OF APPENDAGES (ORBITER)
225	153:56:00	00:04:00	RETRACT/STOW TUG APPENDAGES
226	154:00:00	00:20:00	COMMAND PASSIVATION OF TUG SUBSYSTEMS (ORBITER)
227	154:00:00	00:10:00	VENT & DUMP TUG FLUIDS
228	154:00:00	00:20:00	PASSIVATE TUG SUBSYSTEMS
229	154:20:00	00:05:00	VERIFY TUG/PL SUBSYSTEMS SAFE FOR RETRACTION (ORBITER)
230	154:25:00	00:10:00	RETRACT TUG TO CARGO BAY (ORBITER)
231	154:35:00	00:05:00	MATE/LATCH TUG/PL TO ORBITER BASE RING. VERIFY ATTACHMENT (ORBITER)
232	154:40:00	00:01:00	CONNECT ELECTRICAL UMBILICAL (ORBITER)
233	154:41:00	00:03:00	RELEASE, STOW/DEACTIVATE MANIPULATOR (ORBITER)

Table 5.1-3

Sheet 6

MISSION EVENT NO.	EVENT START TIME HR:MN:SC	EVENT DURATION HR:MN:SC	MISSION PHASES AND EVENTS
234	154:44:00	00:05:00	ROTATE TUG INTO CARGO BAY, CONNECT VENT LINES (ORBITER)
235	154:49:00	00:08:00	SAFE TUG/PL FOR RETURN TO EARTH. INERT TANKS (ORBITER/TUG/PAYLOAD)
236	154:57:00	00:06:00	CONFIGURE CARGO BAY FOR ORBITER ENTRY (ORBITER)
237	155:03:00	00:03:00	CONFIGURE TUG SUBSYSTEMS FOR DEORBIT & ENTRY (ORBITER/TUG)
	155:06:00	12:00:00	PERFORM PRE-DEORBIT COAST OPERATIONS (ORBITER)
	167:06:00	00:05:00	PERFORM DEORBIT MANEUVERS (ORBITER)
	167:11:00	00:42:00	PERFORM ENTRY & DESCENT MANEUVERS (ORBITER)
	167:53:00	00:00:00	PERFORM APPROACH & LANDING



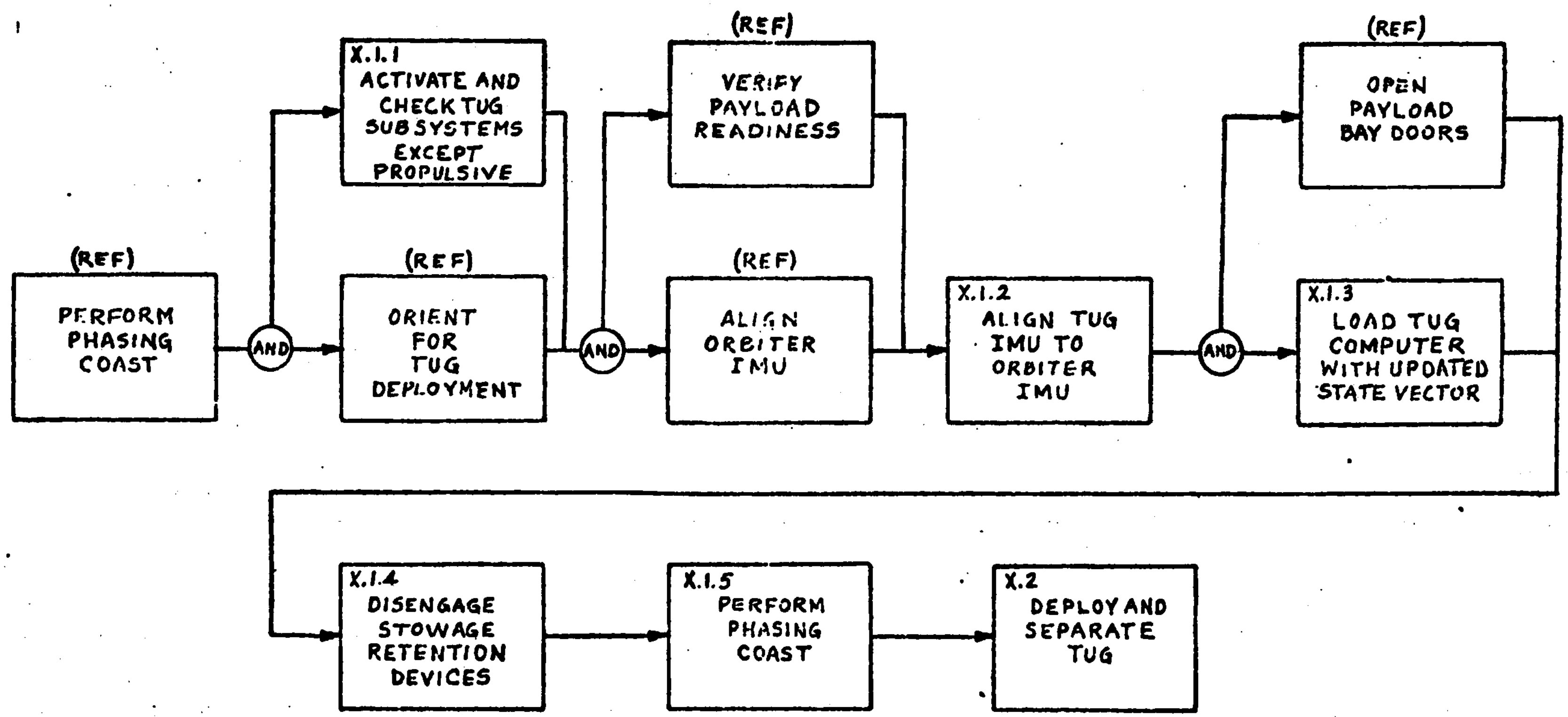
FIRST LEVEL FUNCTIONS

α REFERENCE MISSION

DEPLOYMENT OF 2 PAYLOADS AND RETRIEVAL OF ONE

SYNCHRONOUS EQUATORIAL ORBIT

Figure 5.1-1

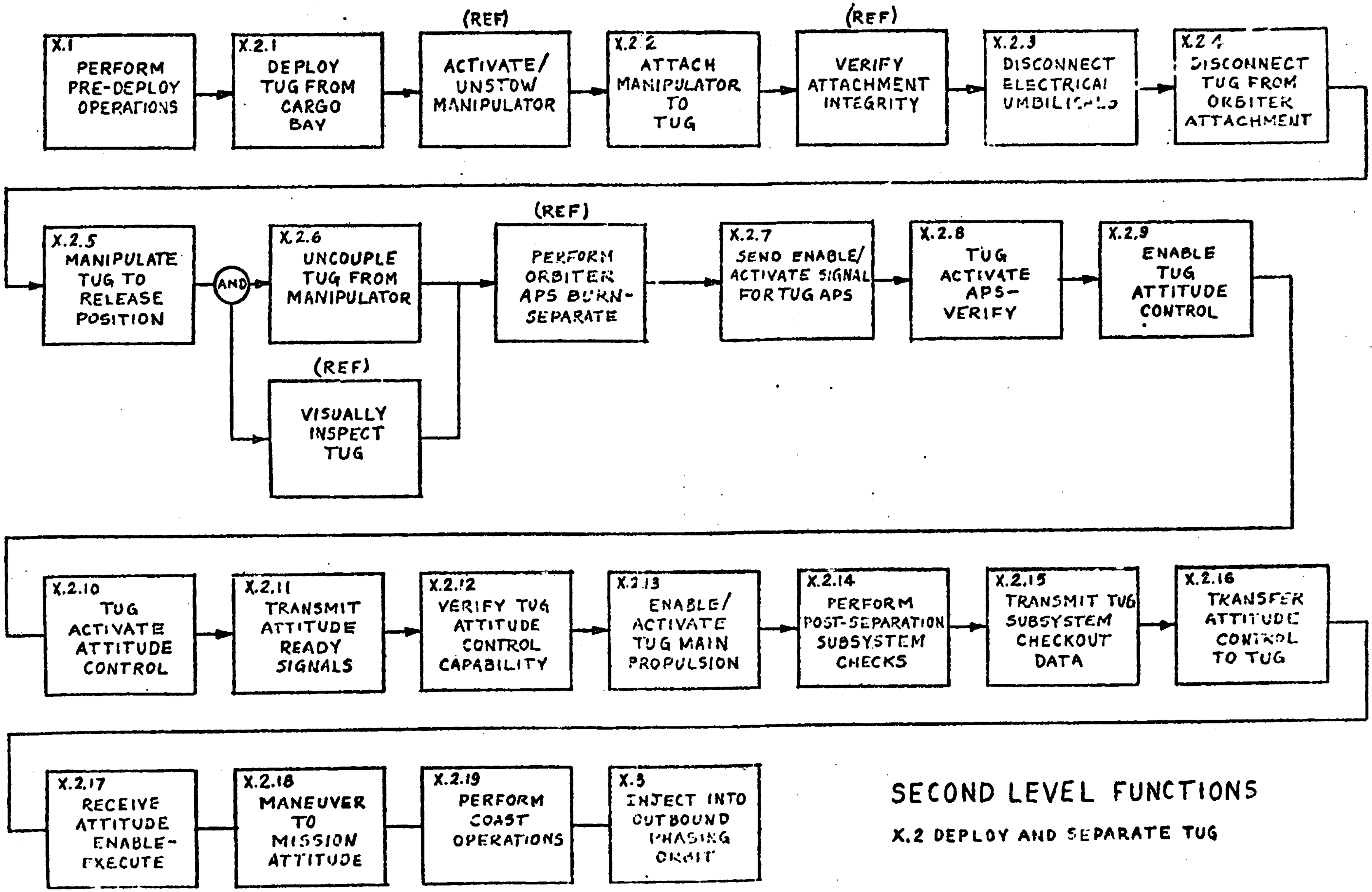


SECOND LEVEL FUNCTIONS

X.1 PERFORM PRE-DEPLOY OPERATIONS

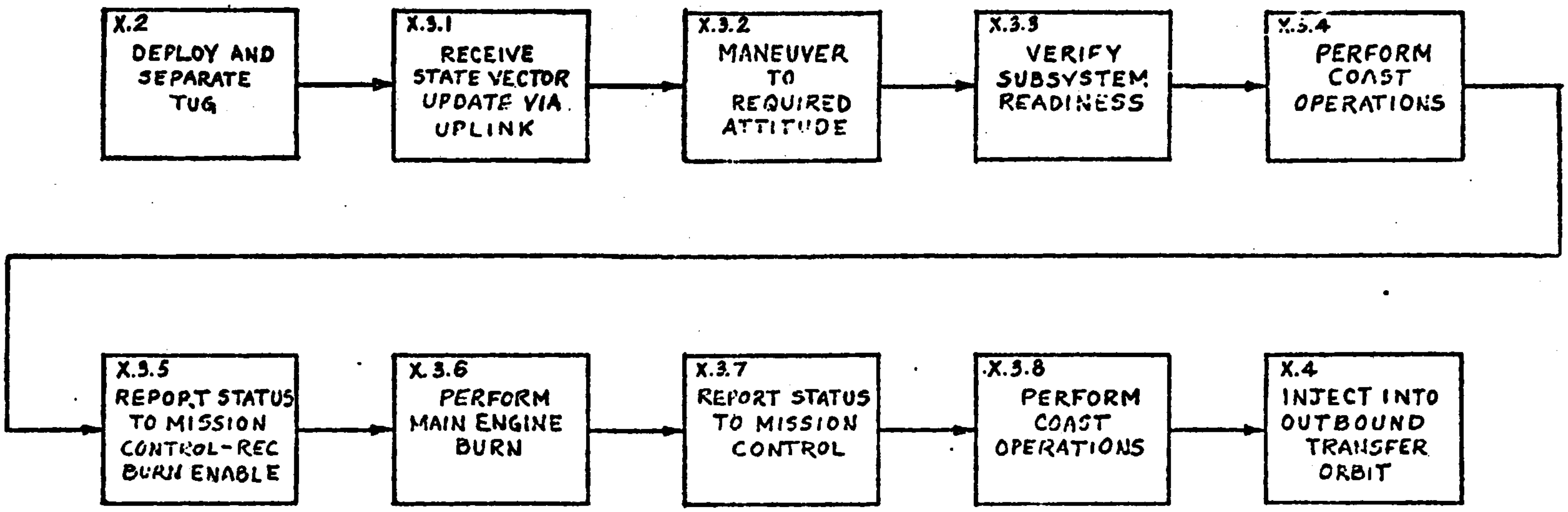
5-11

DOUGLAS



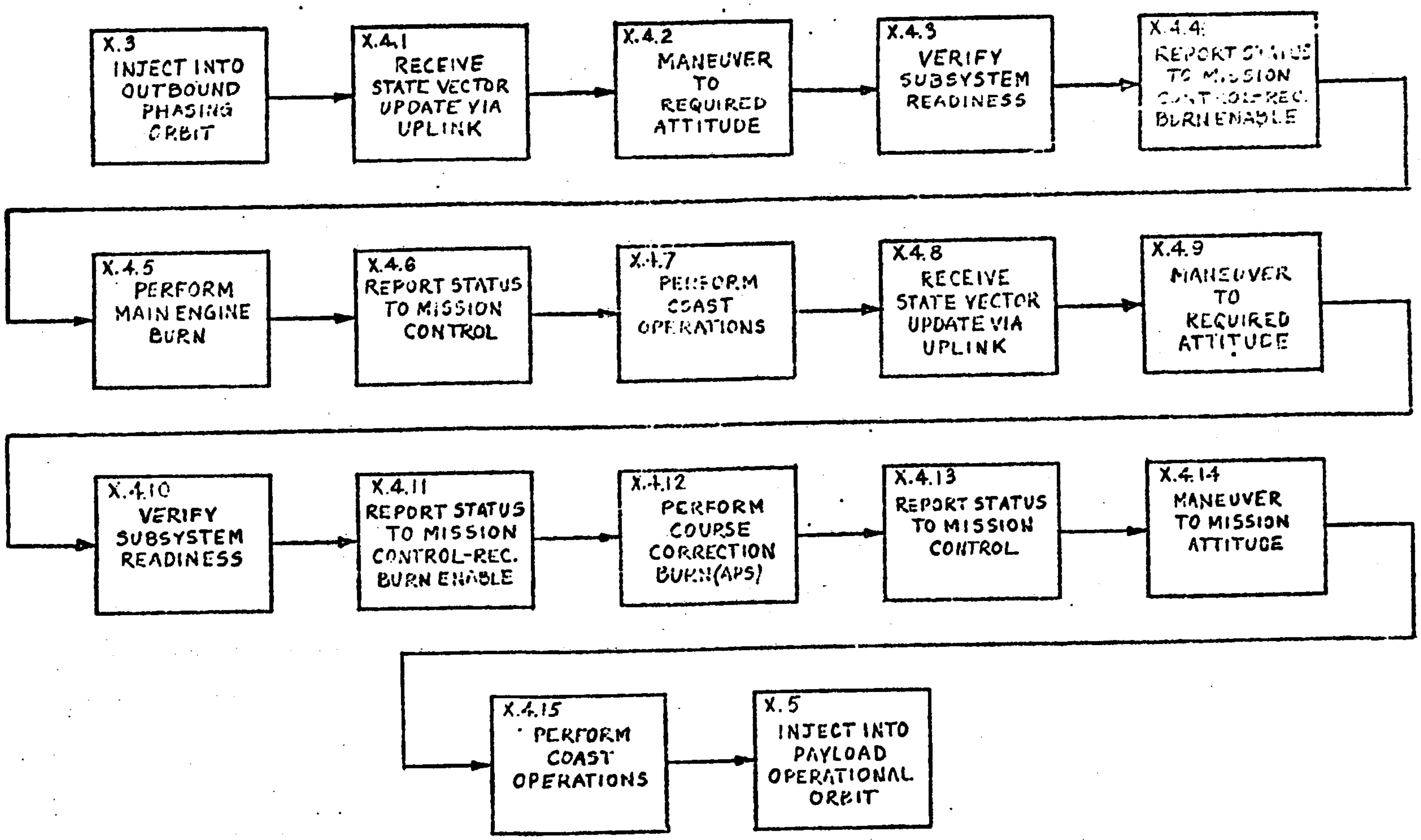
SECOND LEVEL FUNCTIONS

X.2 DEPLOY AND SEPARATE TUG



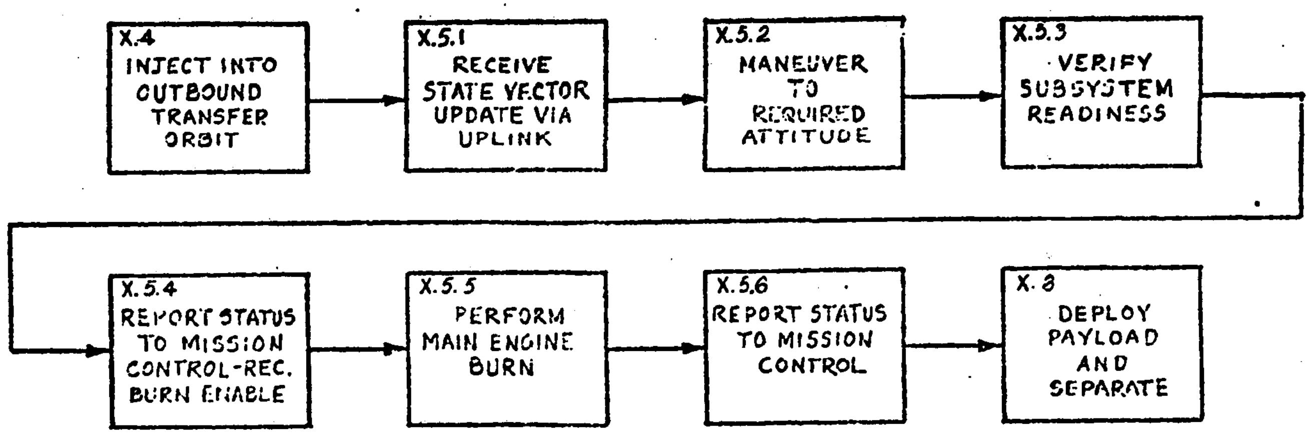
SECOND LEVEL FUNCTIONS

X.3 INJECT INTO OUTBOUND PHASING ORBIT



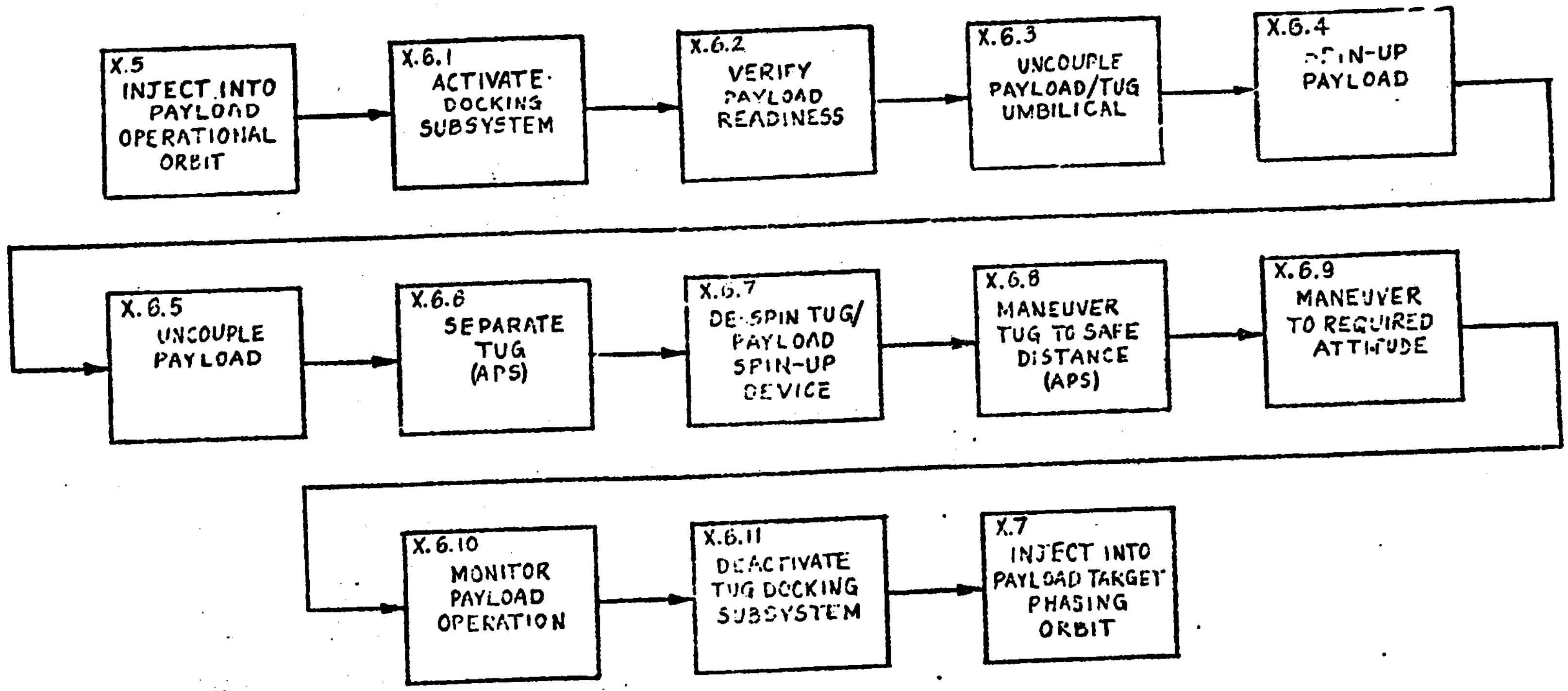
SECOND LEVEL FUNCTIONS

X.4 INJECT INTO OUTBOUND TRANSFER ORBIT



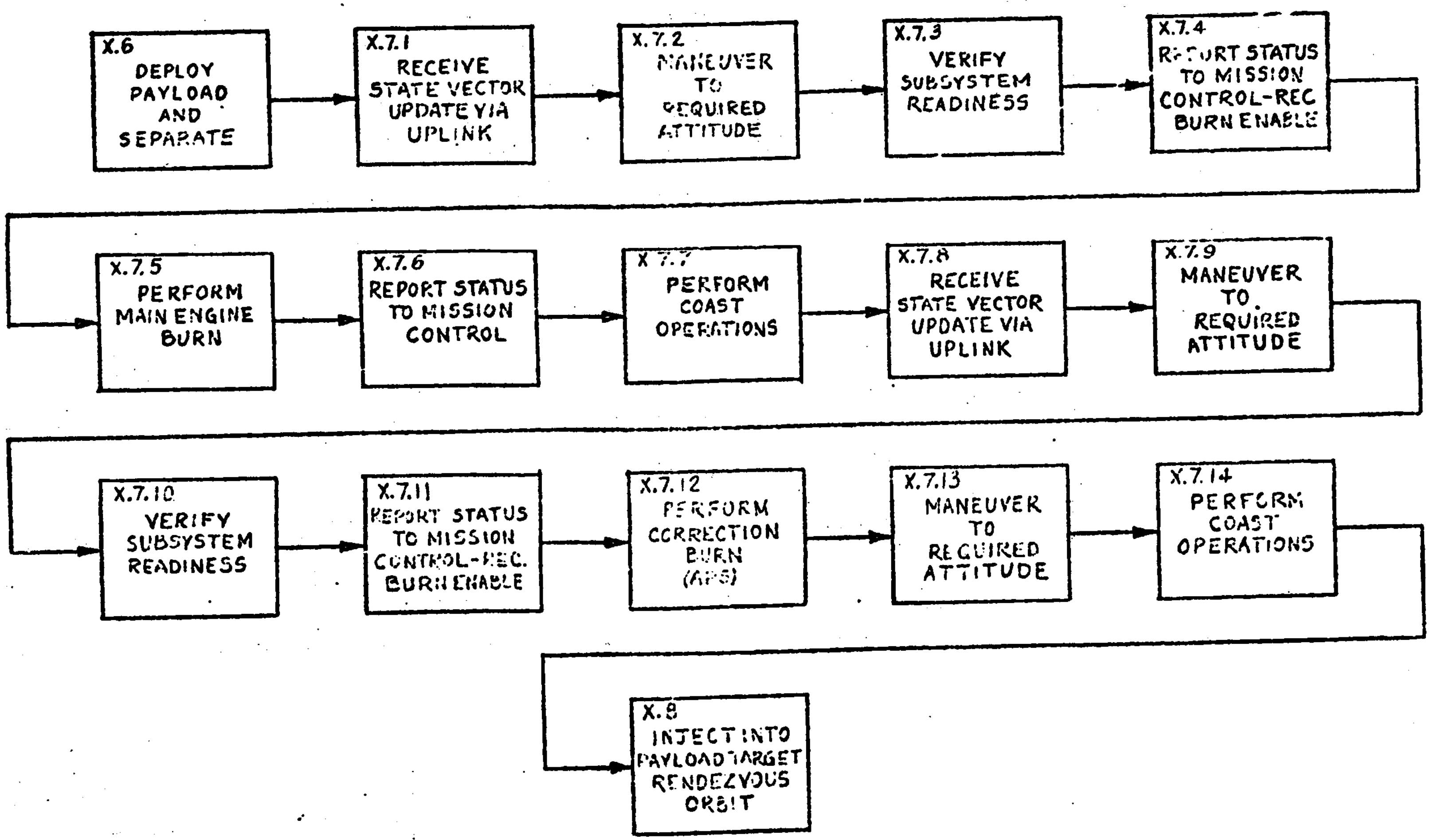
SECOND LEVEL FUNCTIONS

X.5 INJECT INTO PAYLOAD OPERATIONAL ORBIT



SECOND LEVEL FUNCTIONS

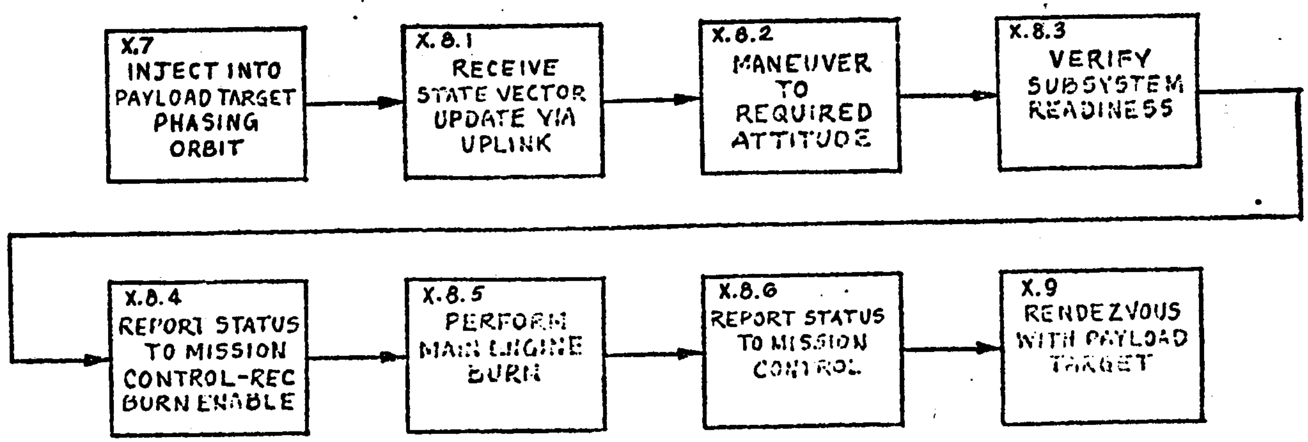
X.6 DEPLOY PAYLOAD AND SEPARATE



SECOND LEVEL FUNCTIONS

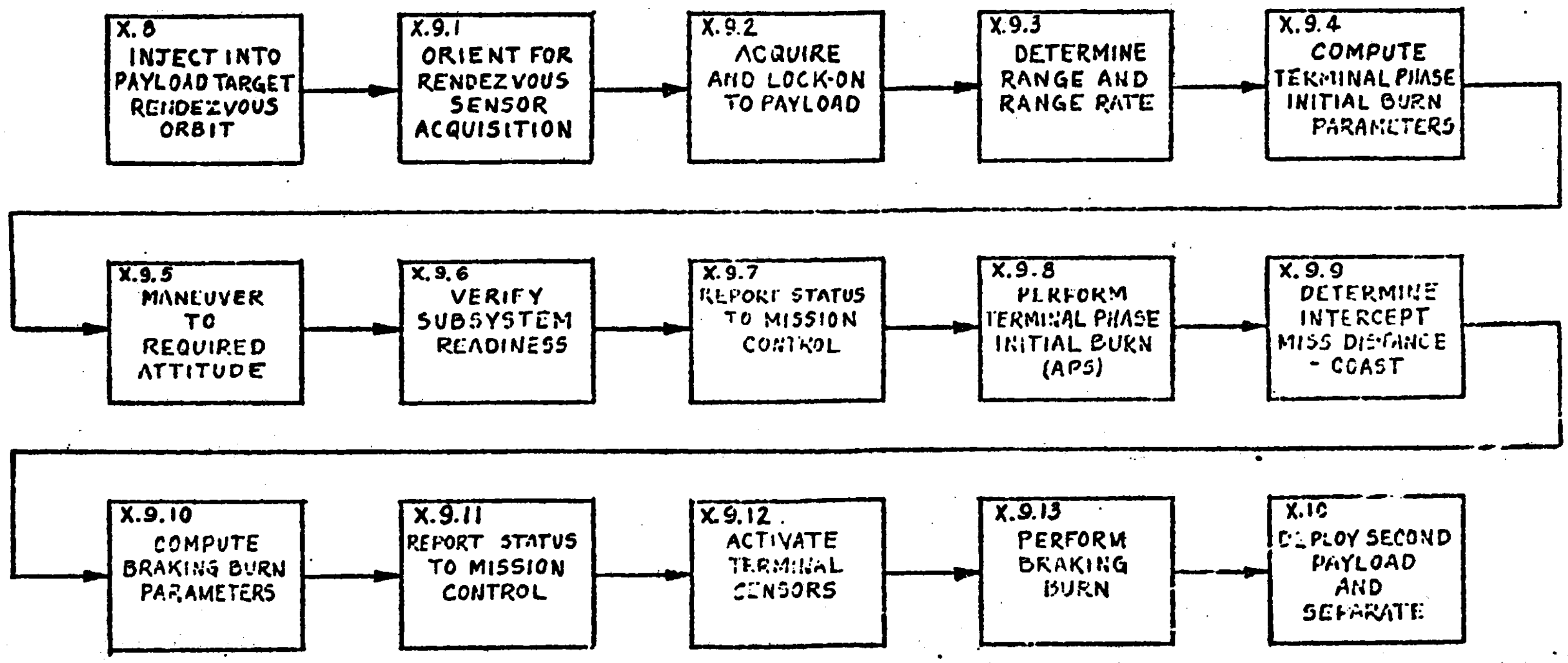
X.7 INJECT INTO PAYLOAD TARGET PHASING ORBIT

DOUGLAS



SECOND LEVEL FUNCTIONS

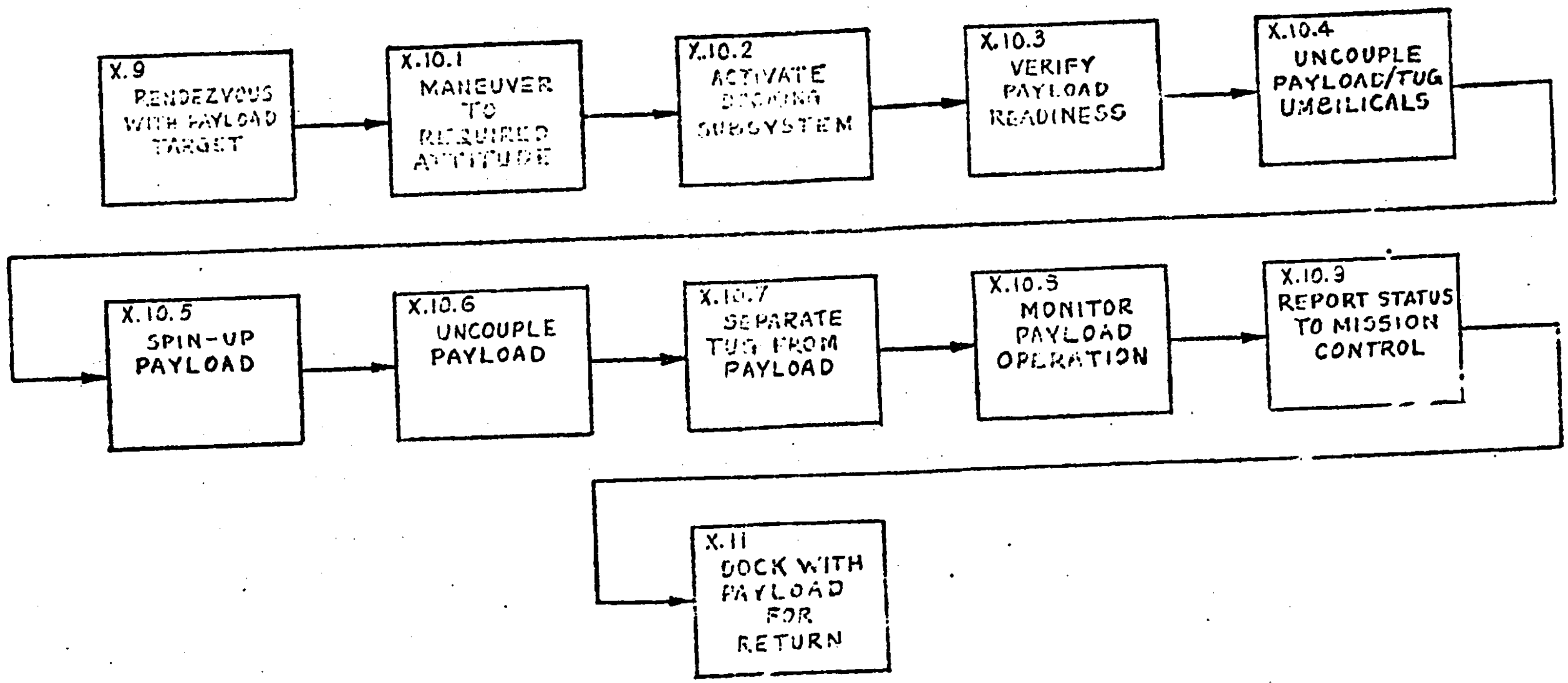
X.8 INJECT INTO PAYLOAD TARGET RENDEZVOUS ORBIT



SECOND LEVEL FUNCTIONS

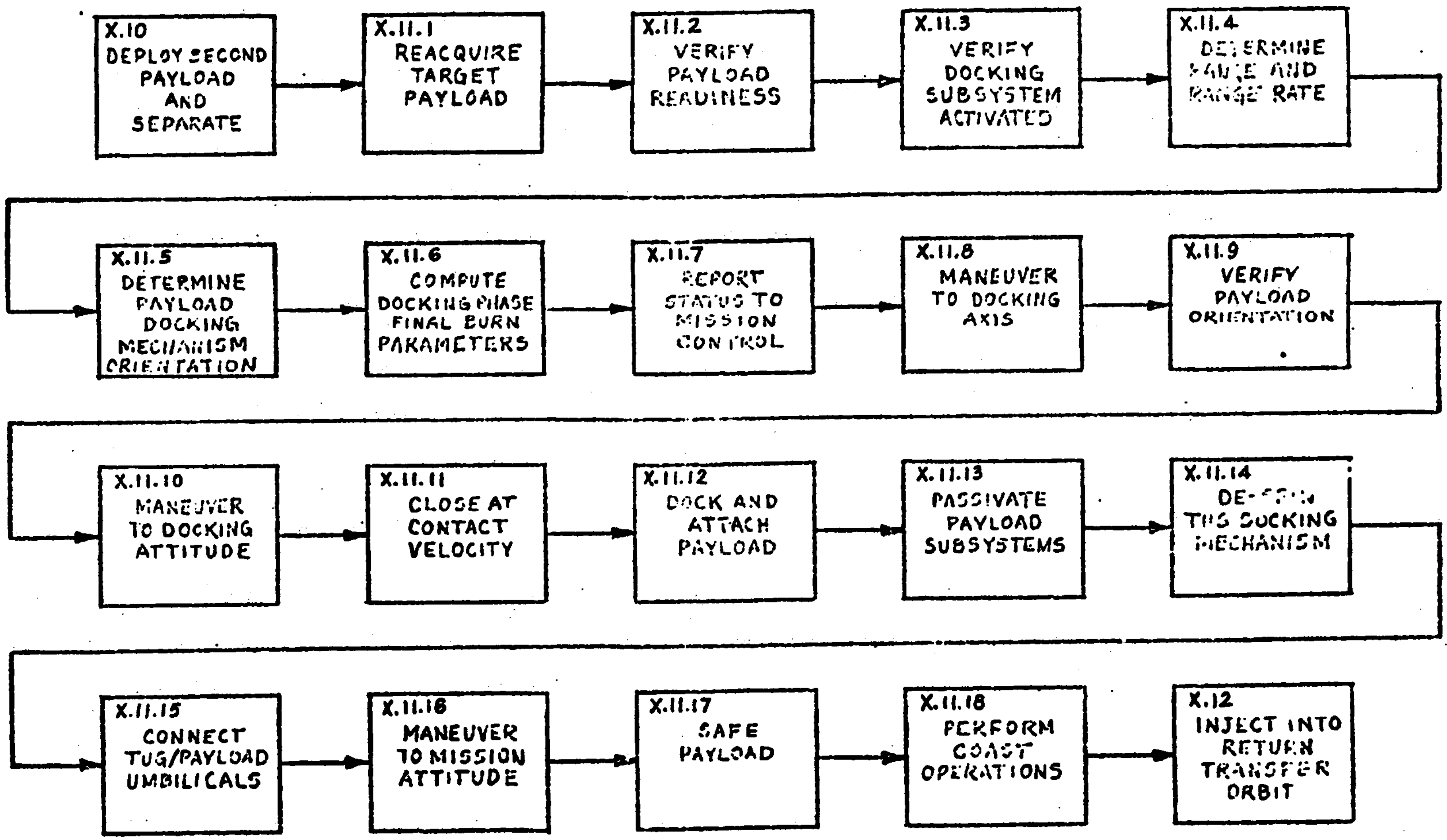
X.9 RENDEZVOUS WITH PAYLOAD TARGET

DOUGLAS



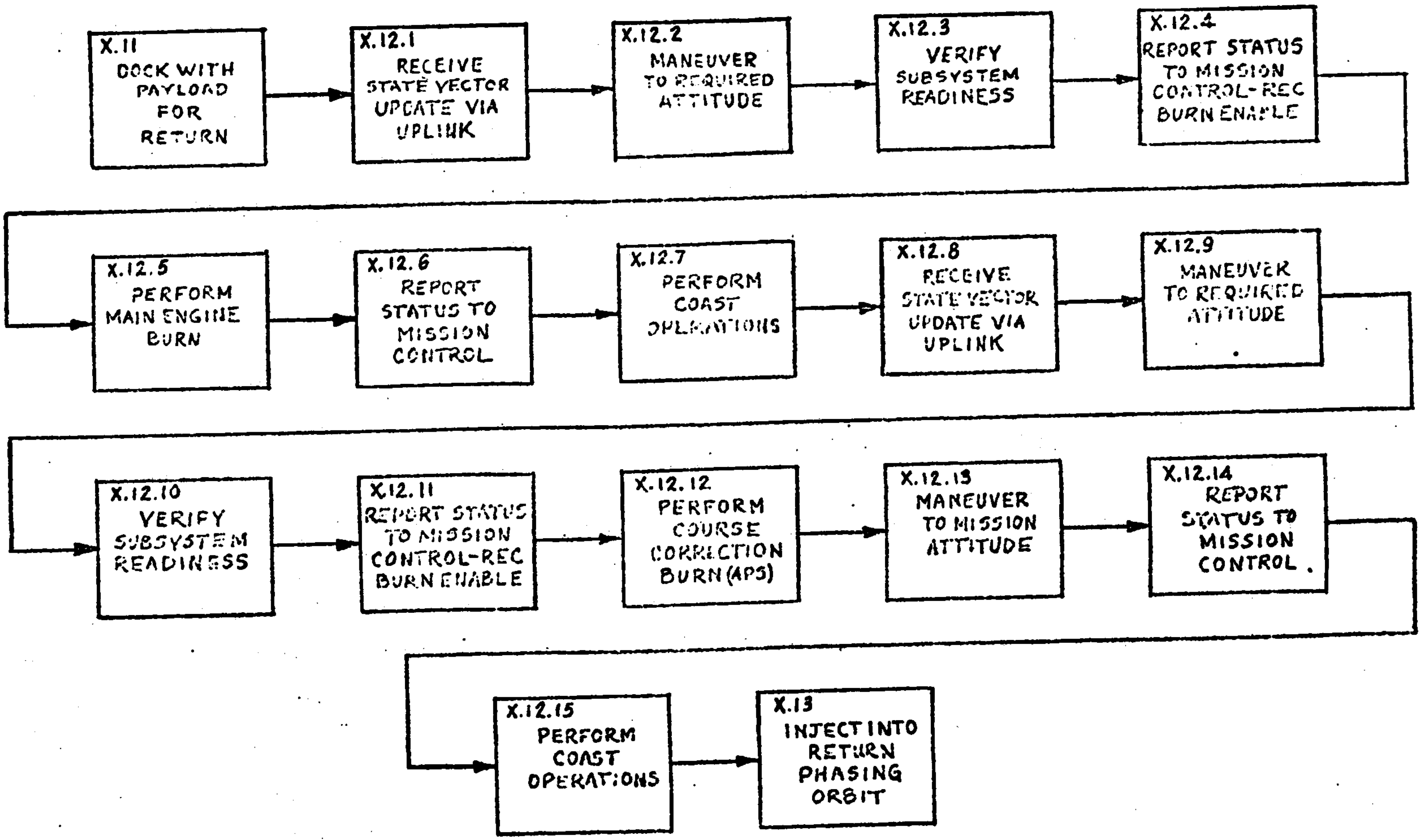
SECOND LEVEL FUNCTIONS

X.10 DEPLOY SECOND PAYLOAD AND SEPARATE



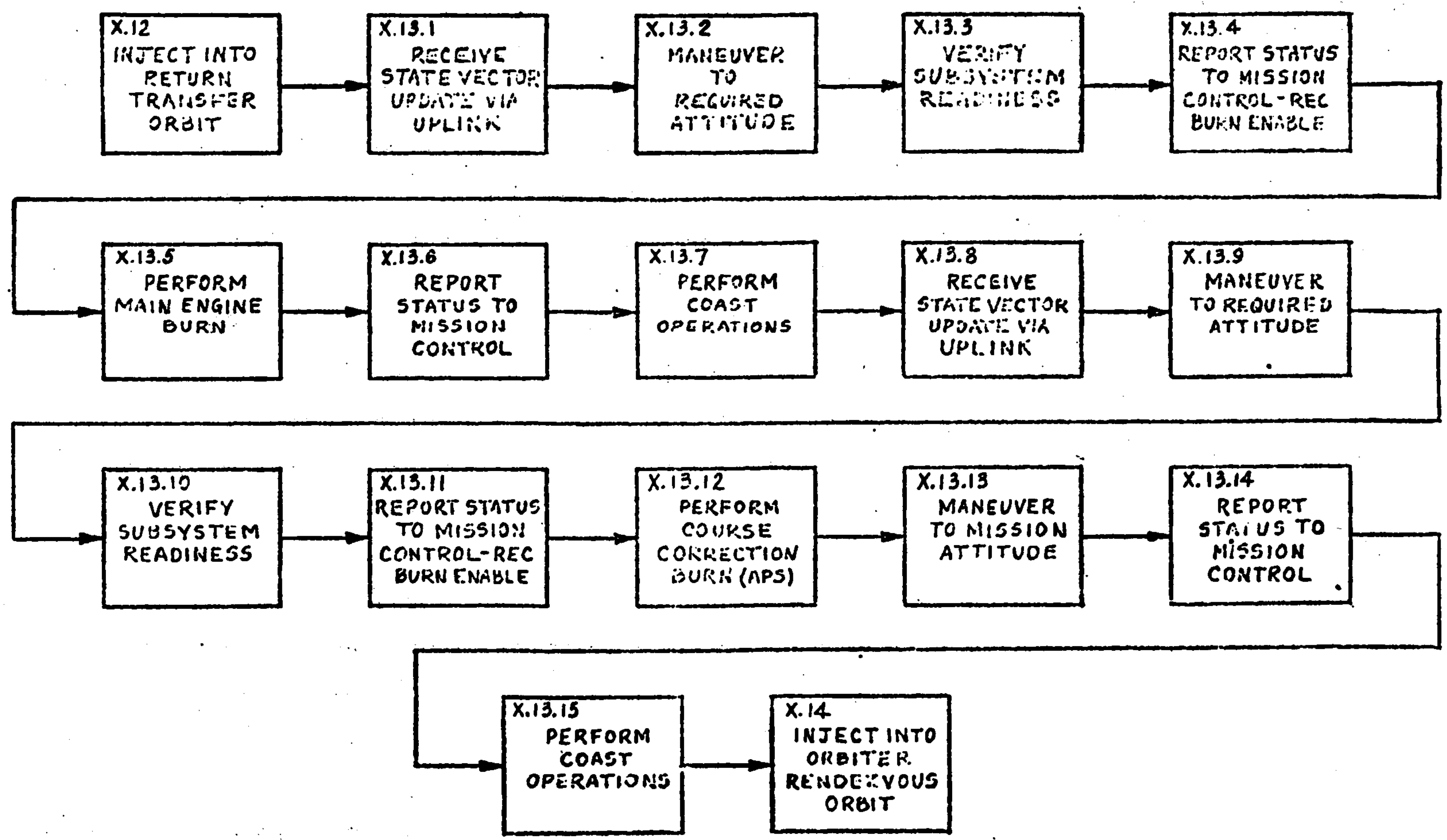
SECOND LEVEL FUNCTIONS

X.11 DOCK WITH PAYLOAD FOR RETURN



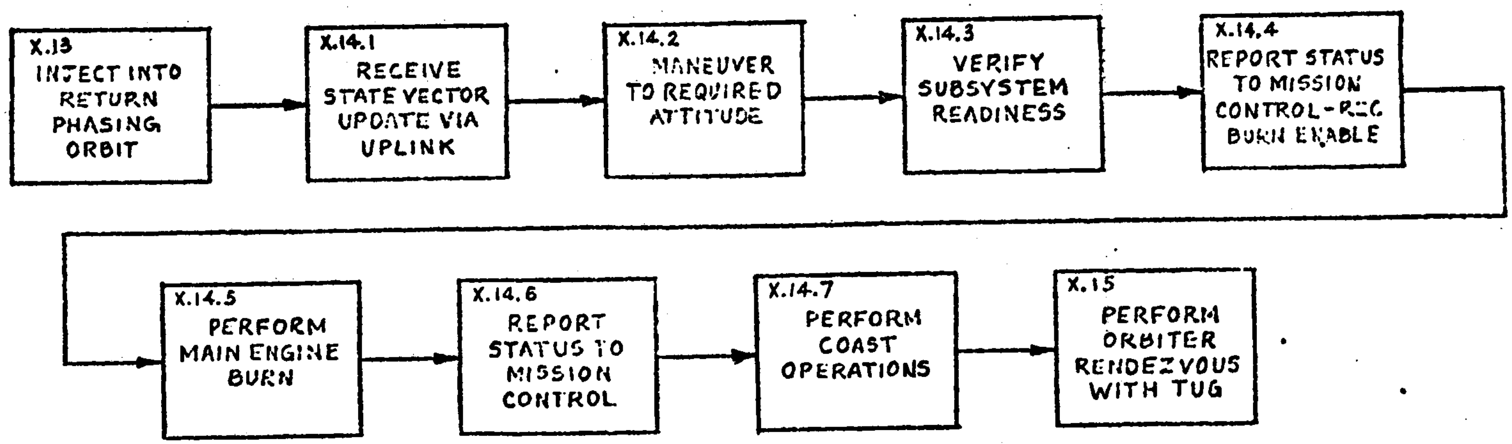
SECOND LEVEL FUNCTIONS

X.12 INJECT INTO RETURN TRANSFER ORBIT



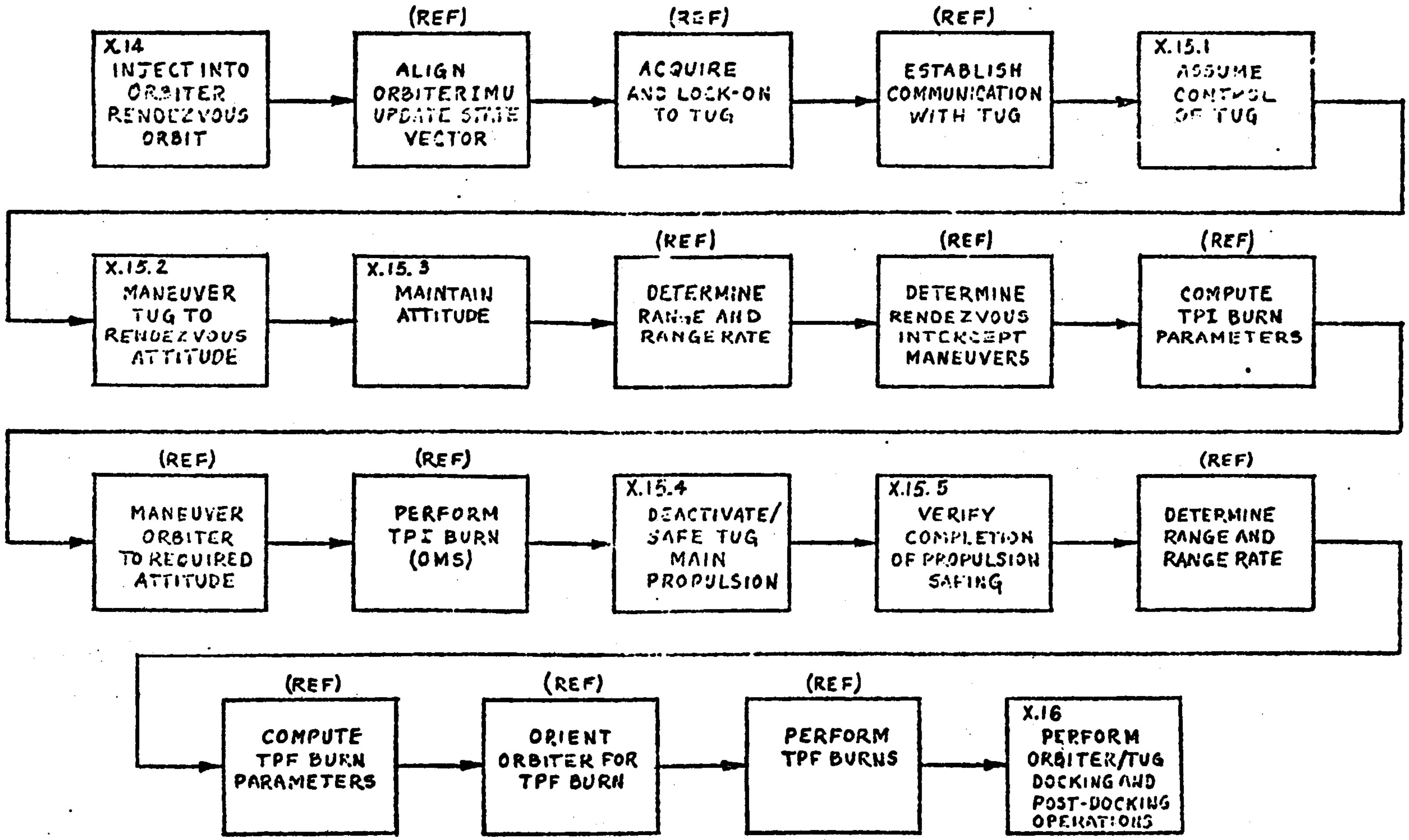
SECOND LEVEL FUNCTIONS

X.13 INJECT INTO RETURN PHASING ORBIT



SECOND LEVEL FUNCTIONS

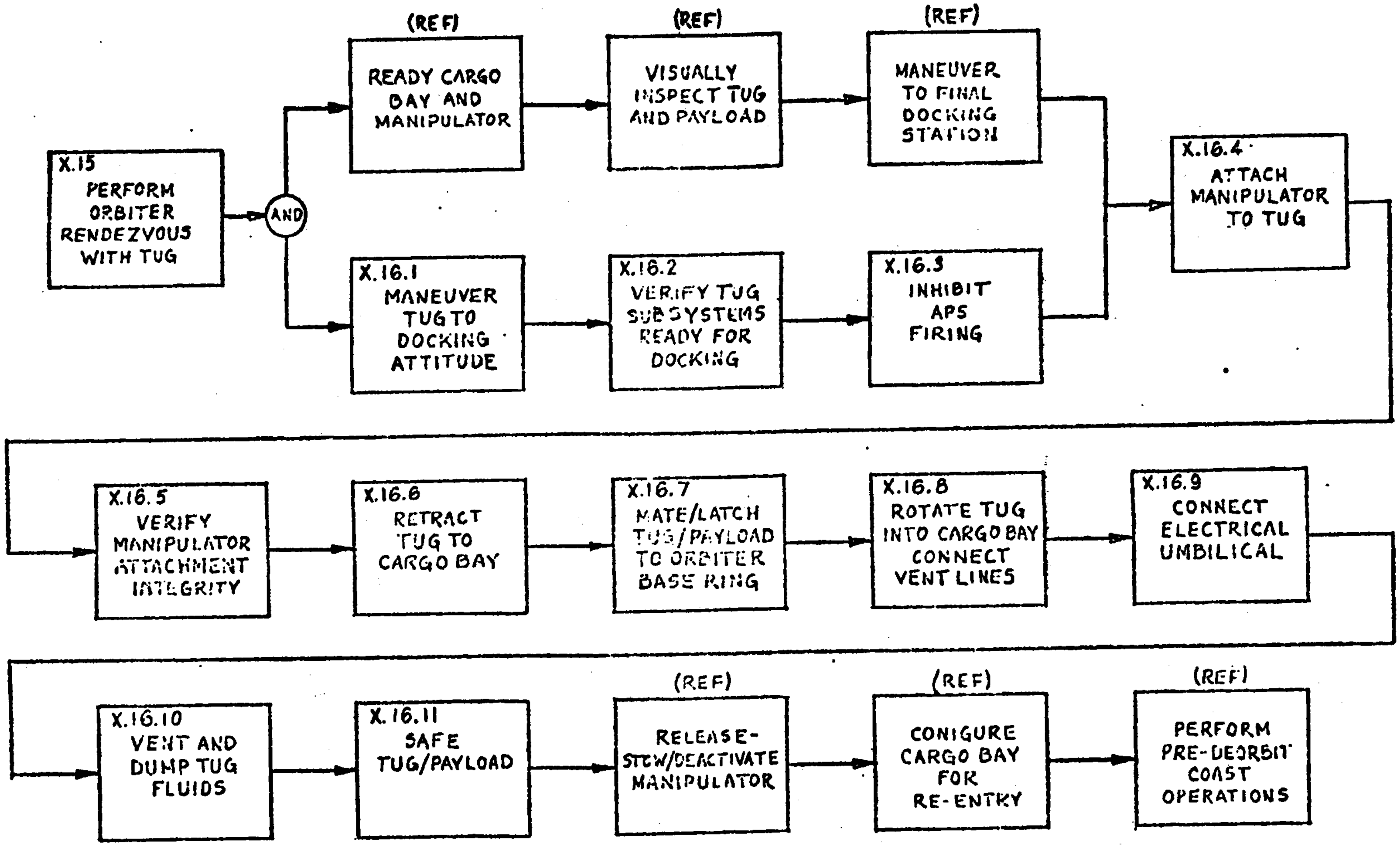
X.14 INJECT INTO ORBITER RENDEZVOUS ORBIT



SECOND LEVEL FUNCTIONS

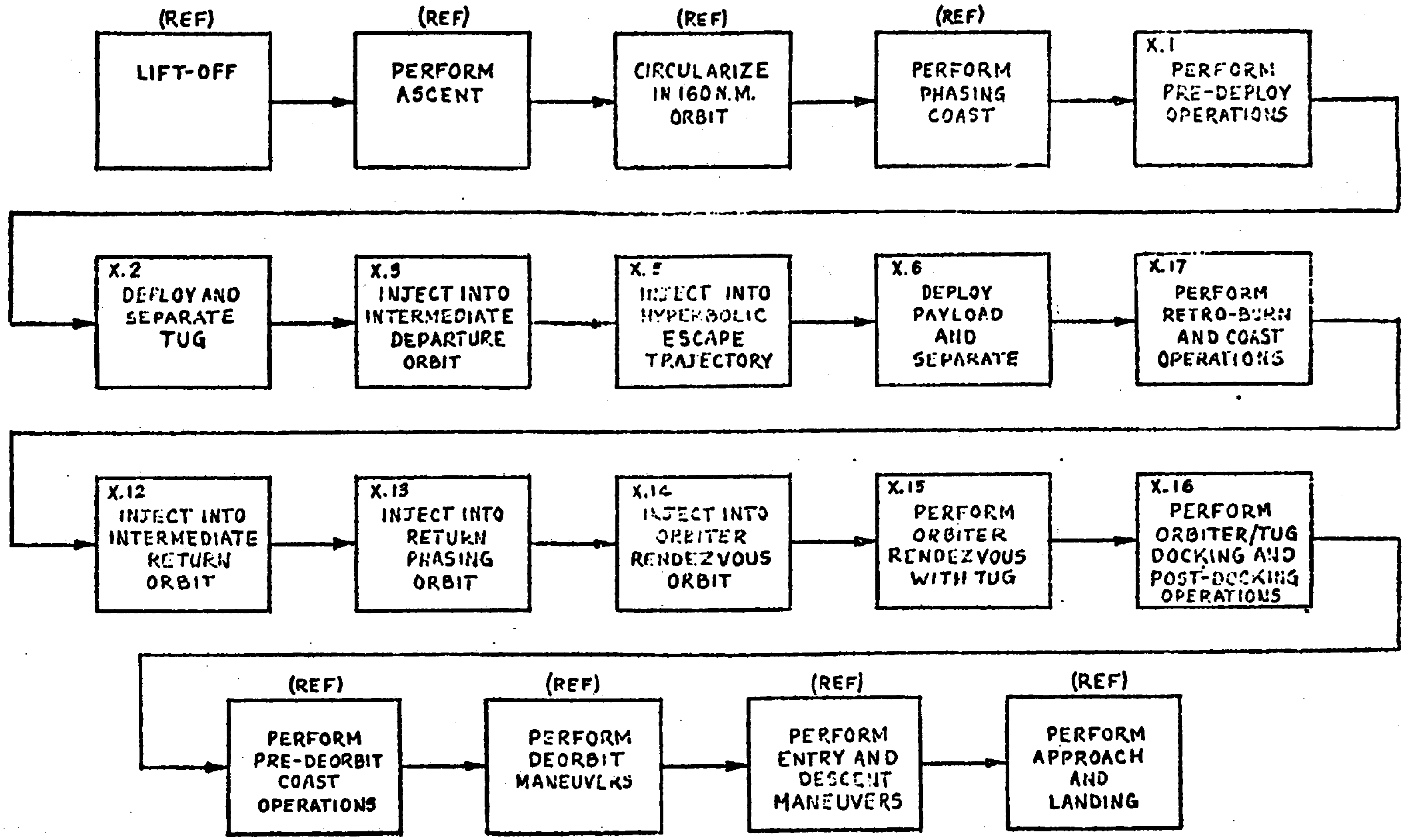
X.15 PERFORM ORBITER RENDEZVOUS WITH TUG

DOUGLAS



SECOND LEVEL FUNCTIONS

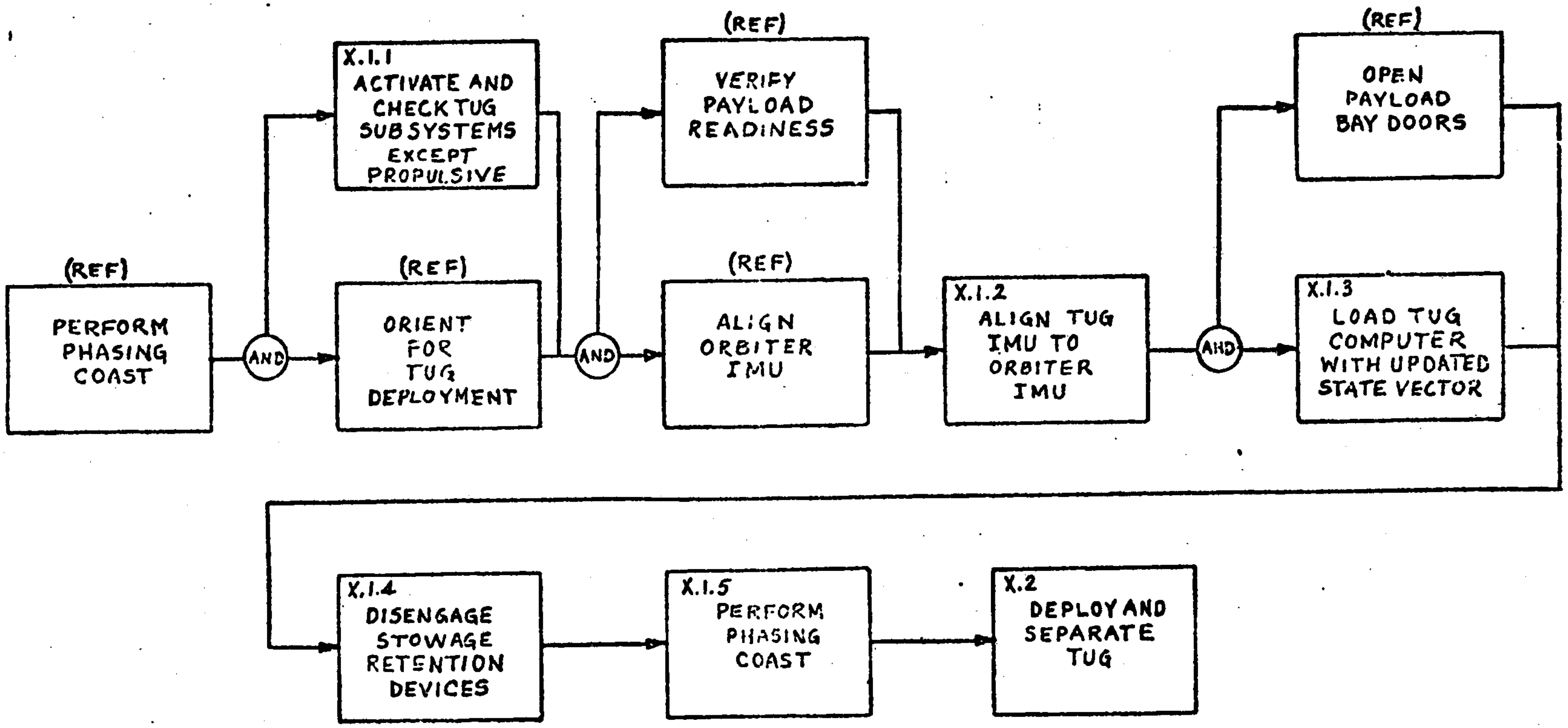
X.16 PERFORM ORBITER/TUG DOCKING AND POST-DOCKING OPERATIONS



FIRST LEVEL FUNCTIONS

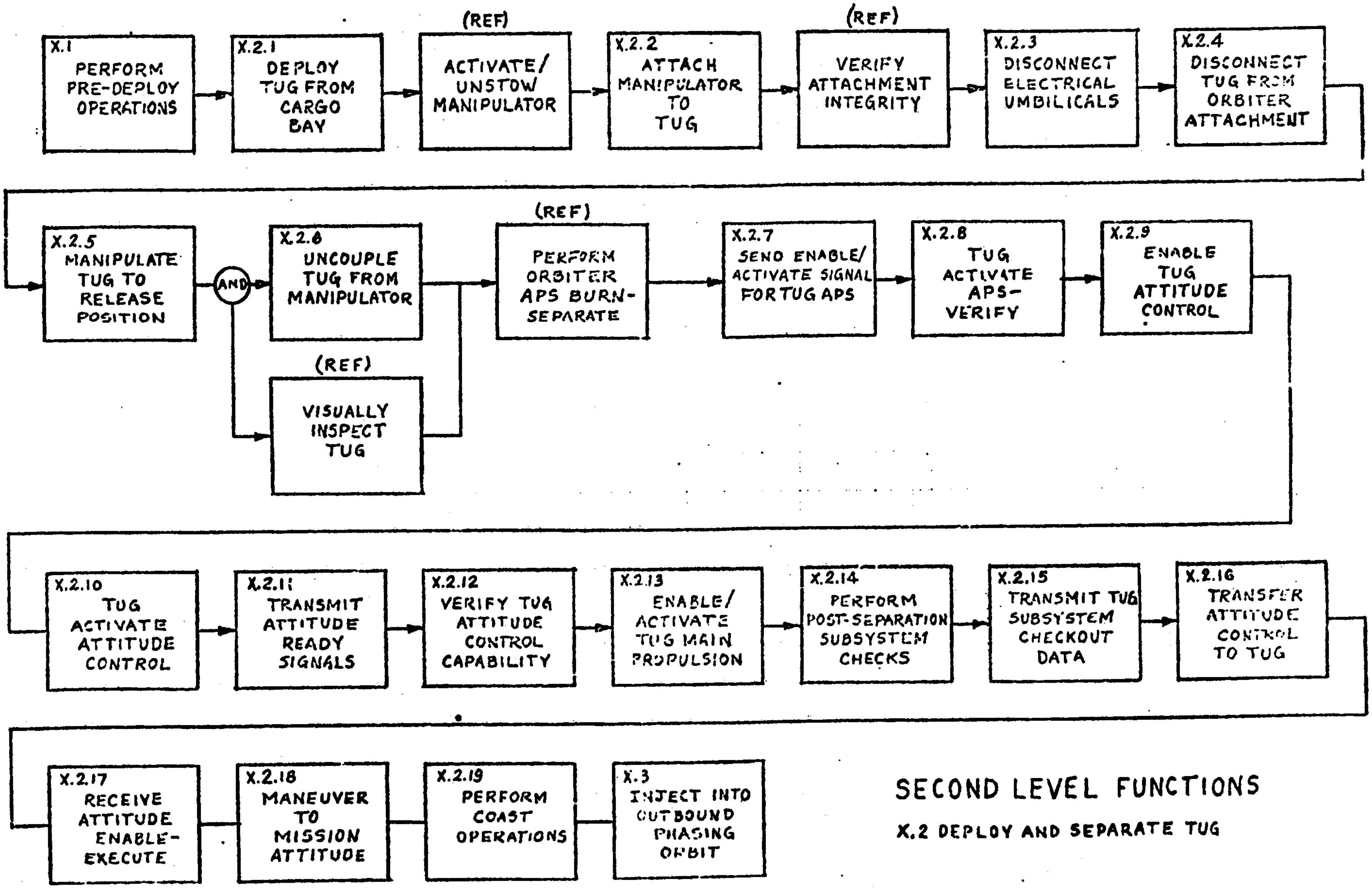
γ REFERENCE MISSION

DEPLOYMENT ON PLANETARY TRAJECTORY



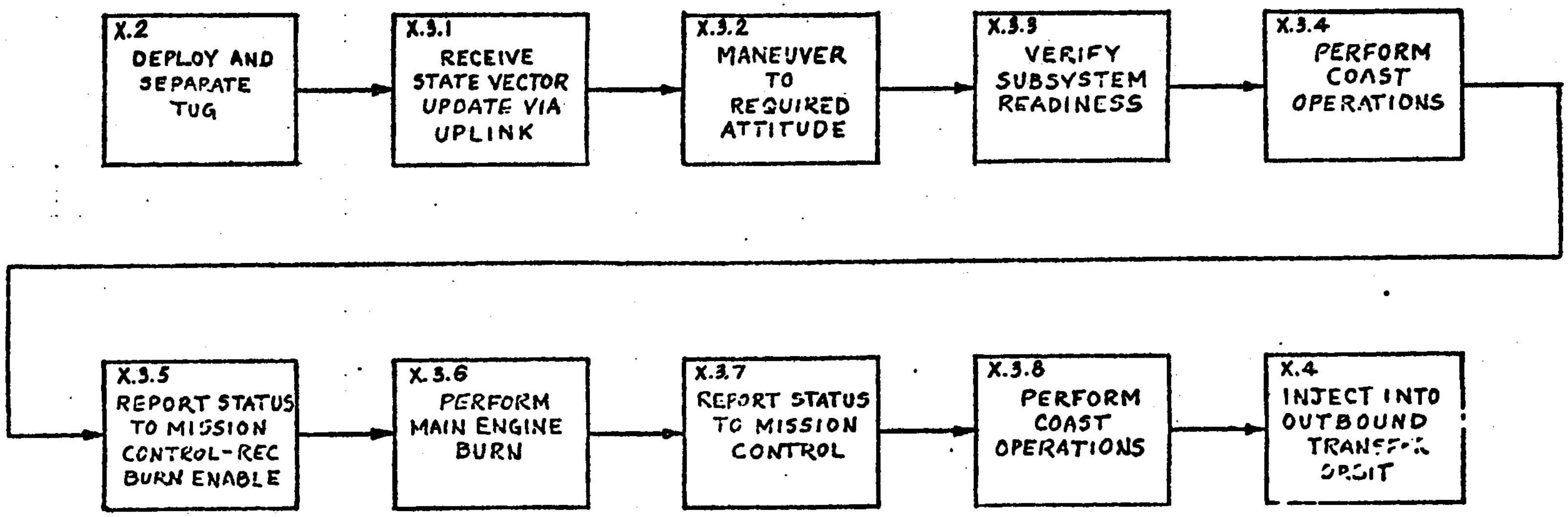
SECOND LEVEL FUNCTIONS

X.i PERFORM PRE-DEPLOY OPERATIONS



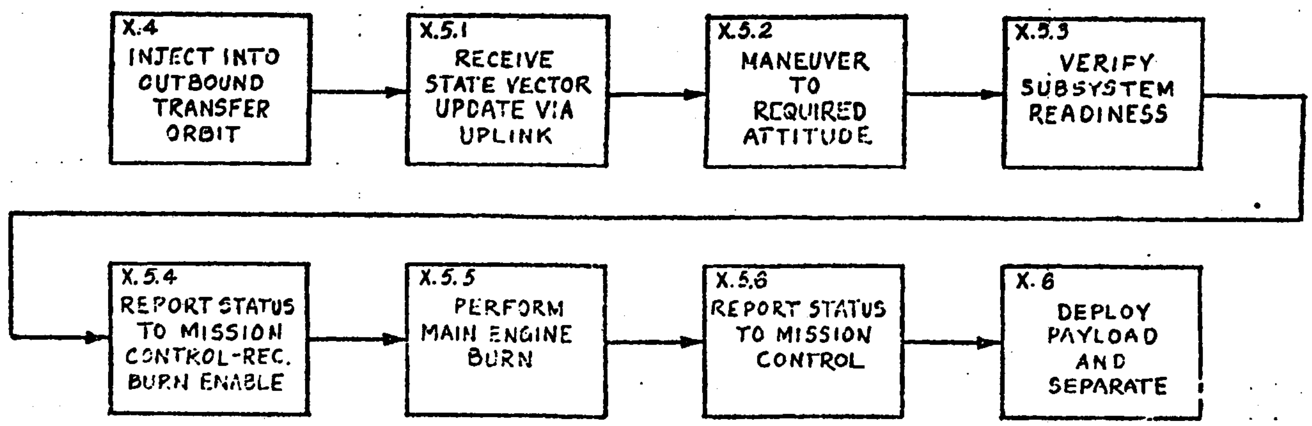
SECOND LEVEL FUNCTIONS

X.2 DEPLOY AND SEPARATE TUG



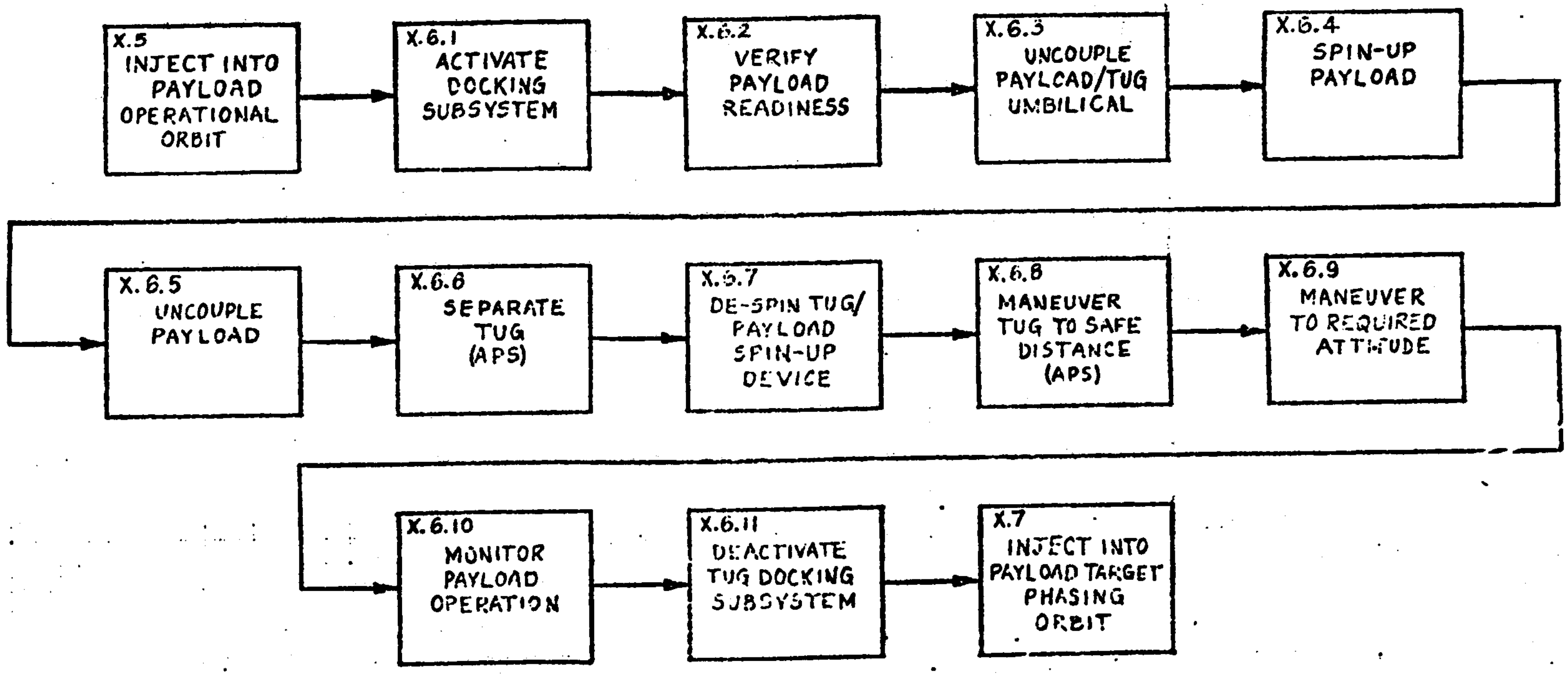
SECOND LEVEL FUNCTIONS

X.3 INJECT INTO OUTBOUND PHASING ORBIT



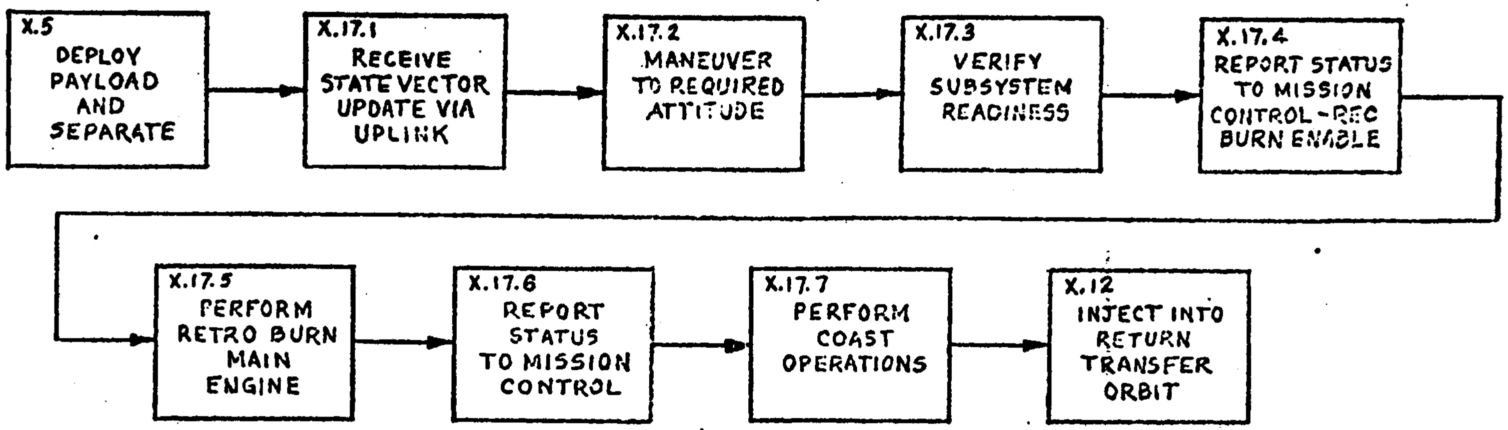
SECOND LEVEL FUNCTIONS

X.5 INJECT INTO PAYLOAD OPERATIONAL ORBIT



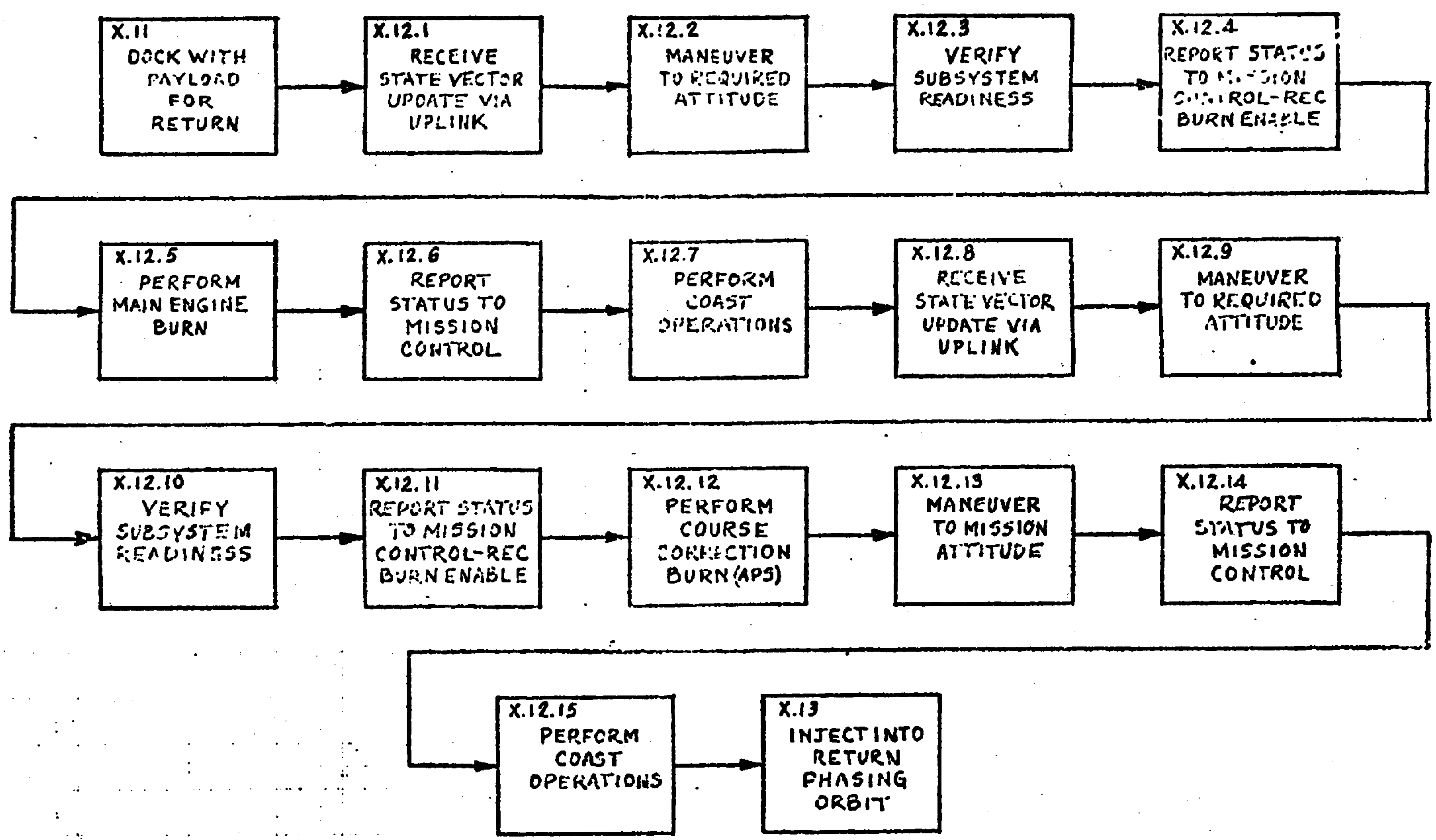
SECOND LEVEL FUNCTIONS

X.6 DEPLOY PAYLOAD AND SEPARATE



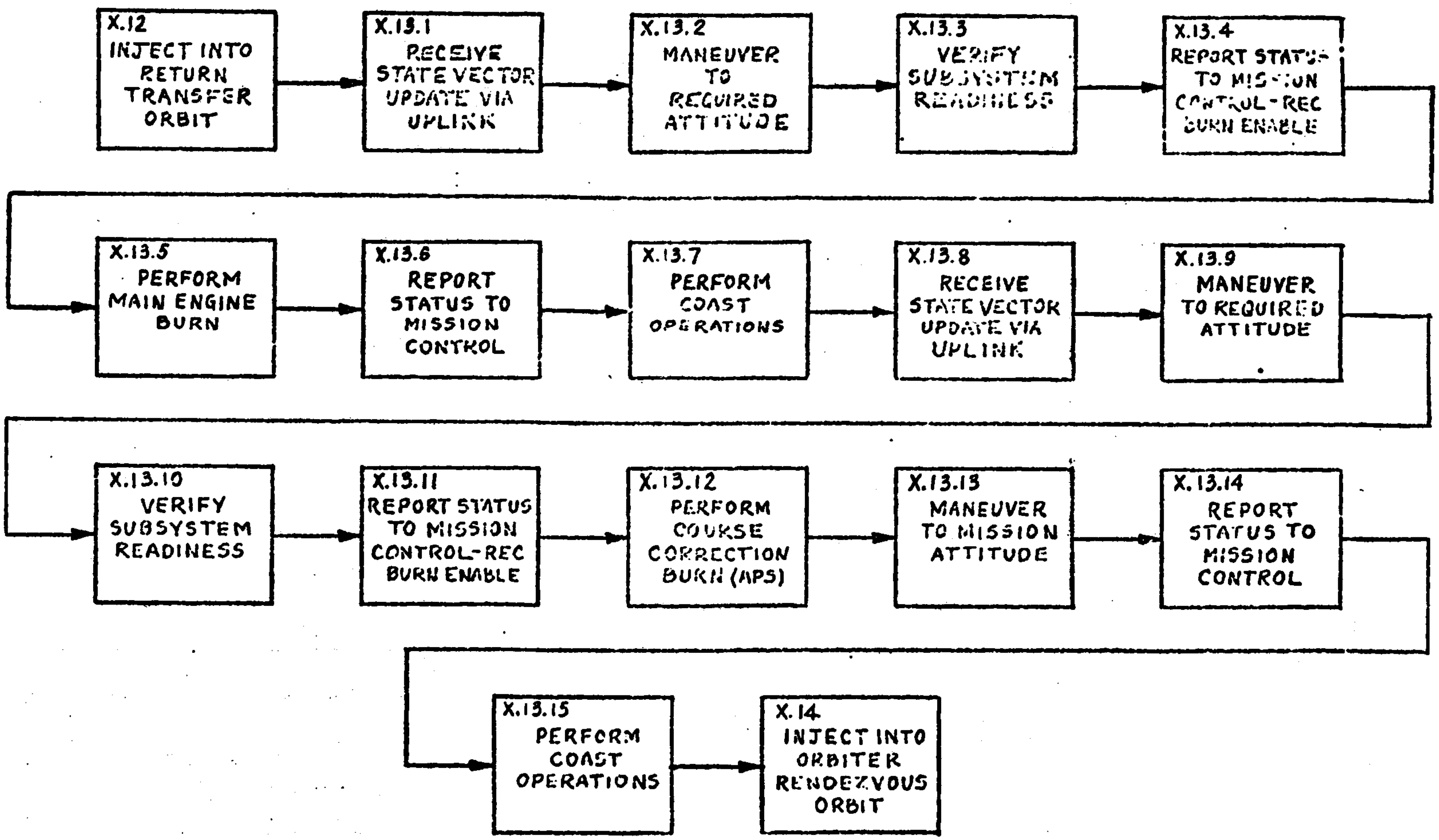
SECOND LEVEL FUNCTIONS

X.17 PERFORM RETRO-BURN AND COAST OPERATIONS



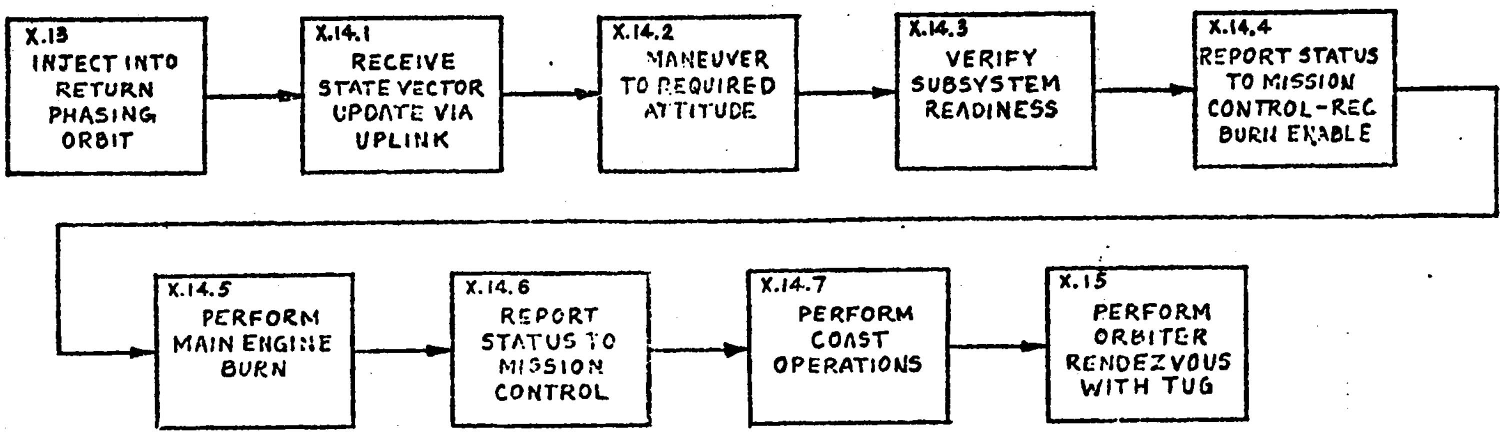
SECOND LEVEL FUNCTIONS

X.12 INJECT INTO RETURN TRANSFER ORBIT



SECOND LEVEL FUNCTIONS

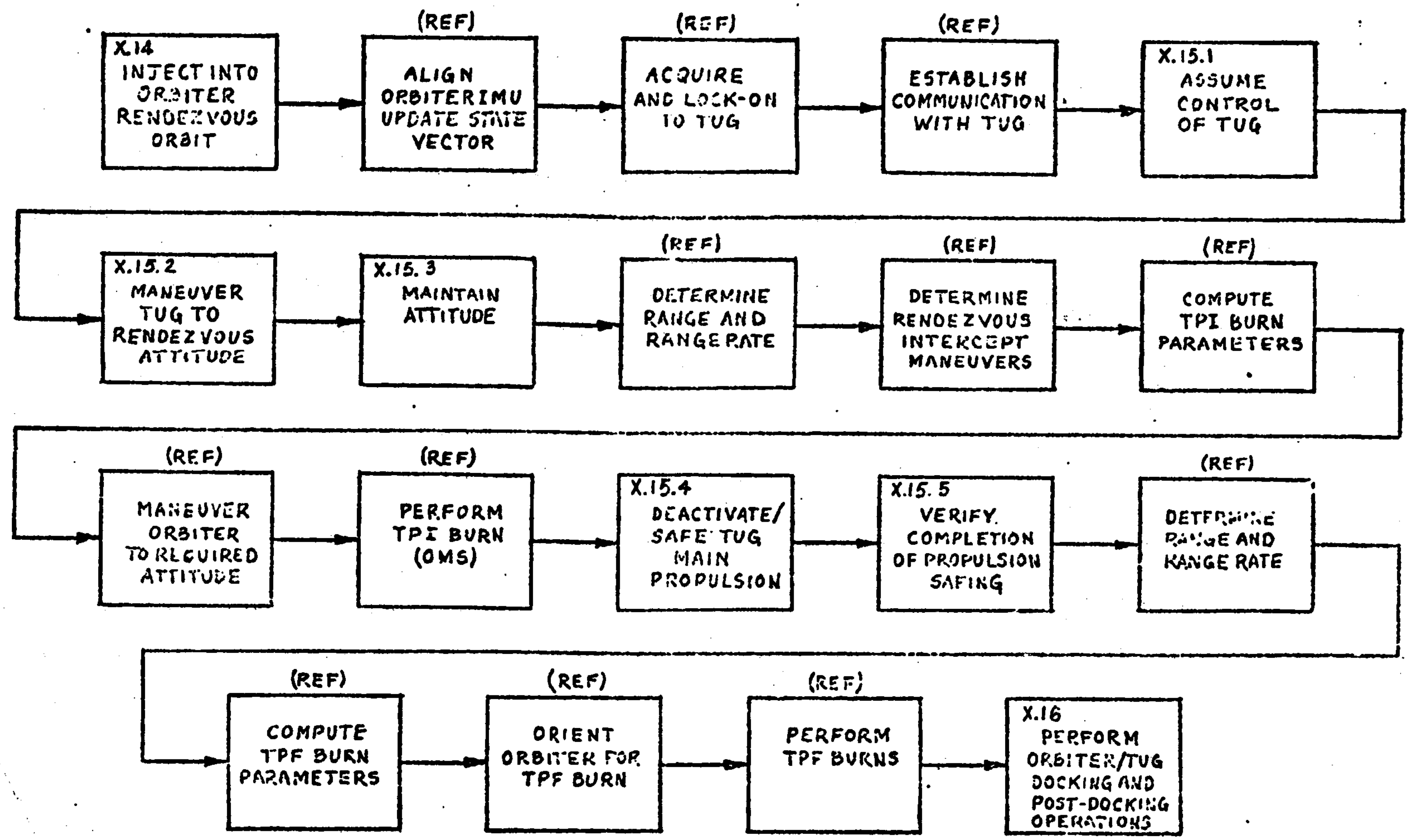
X.13 INJECT INTO RETURN PHASING ORBIT



SECOND LEVEL FUNCTIONS

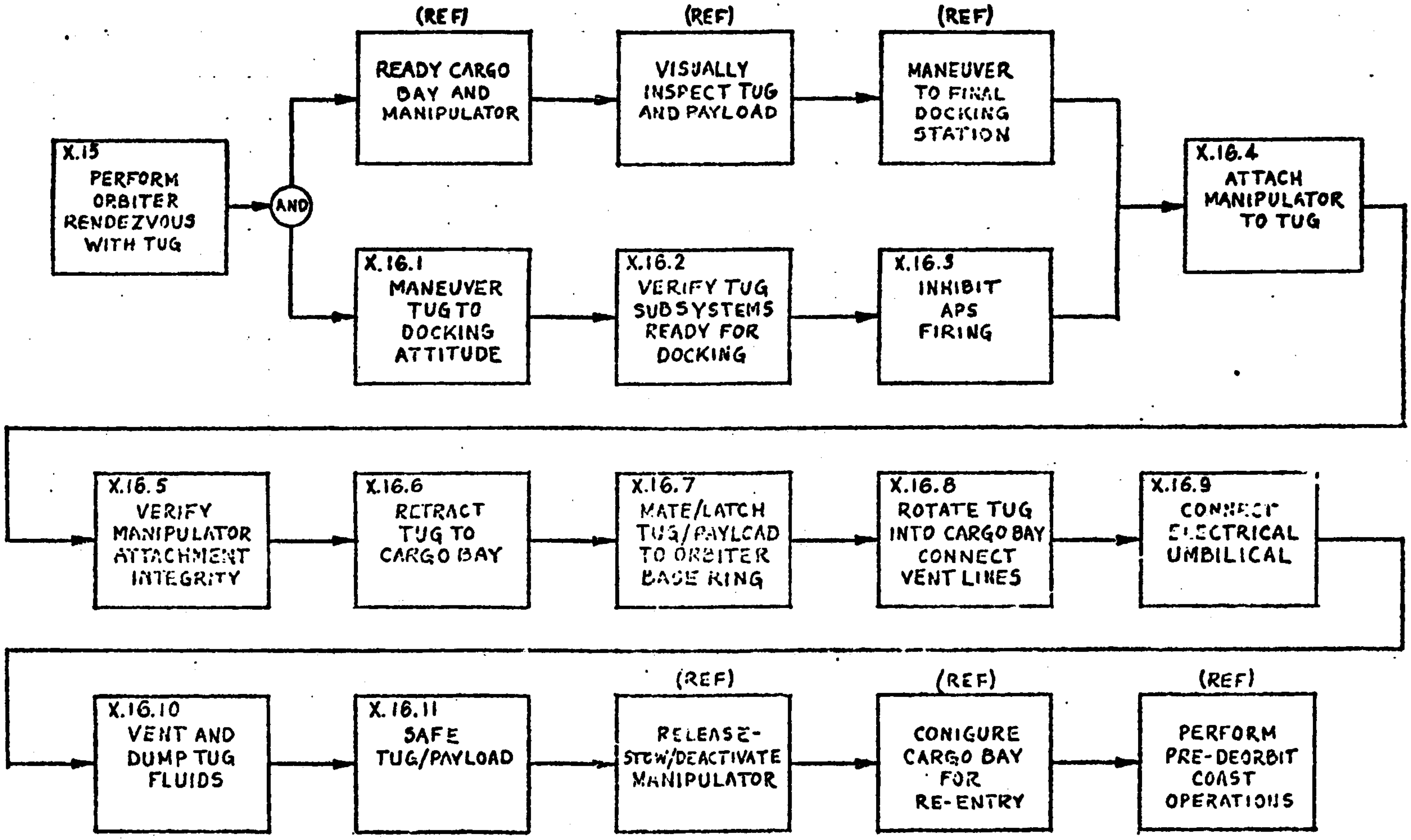
X.14 INJECT INTO ORBITER RENDEZVOUS ORBIT

DOUGLAS



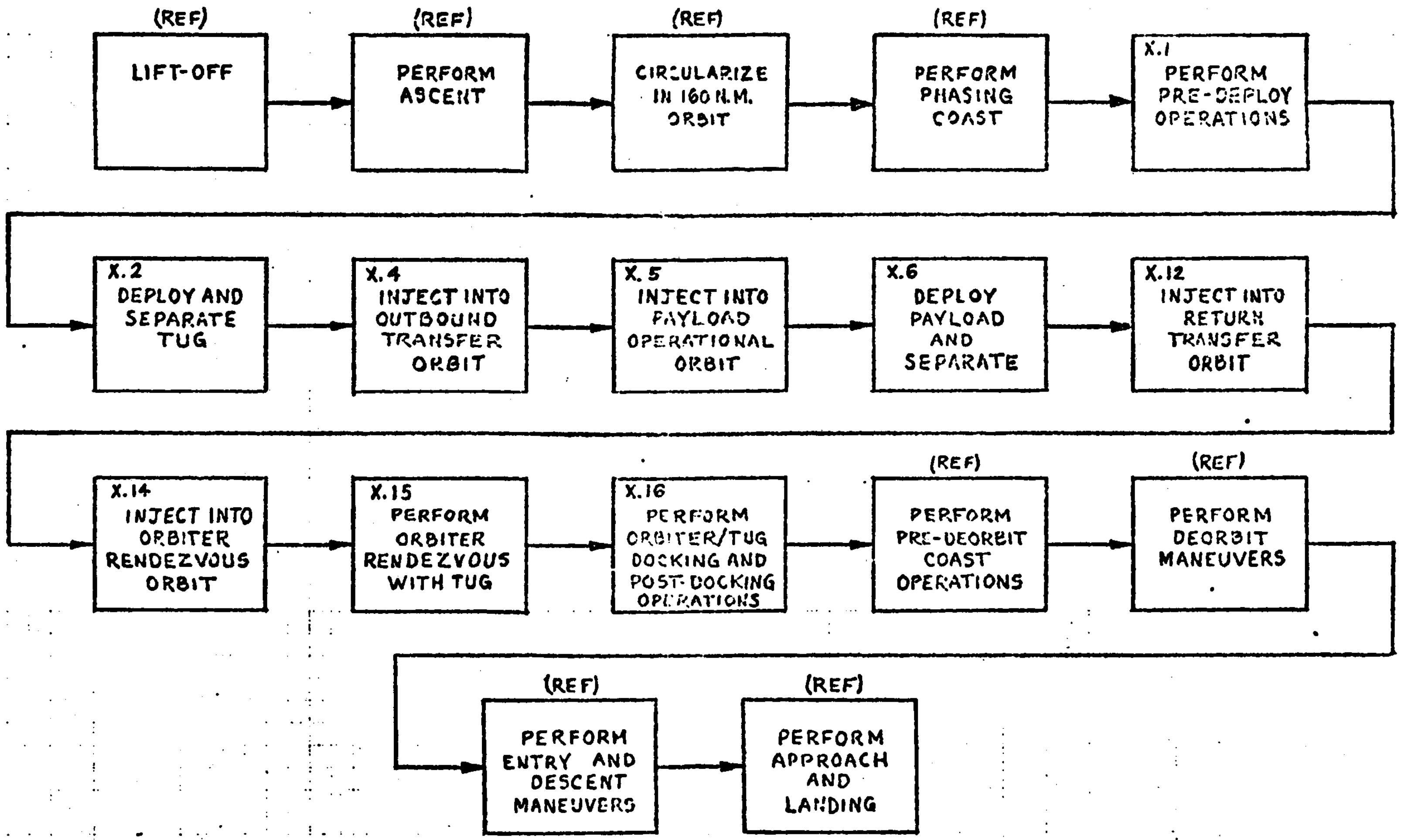
SECOND LEVEL FUNCTIONS

X.15 PERFORM ORBITER RENDEZVOUS WITH TUG



SECOND LEVEL FUNCTIONS

X.16 PERFORM ORBITER/TUG DOCKING AND POST-DOCKING OPERATIONS

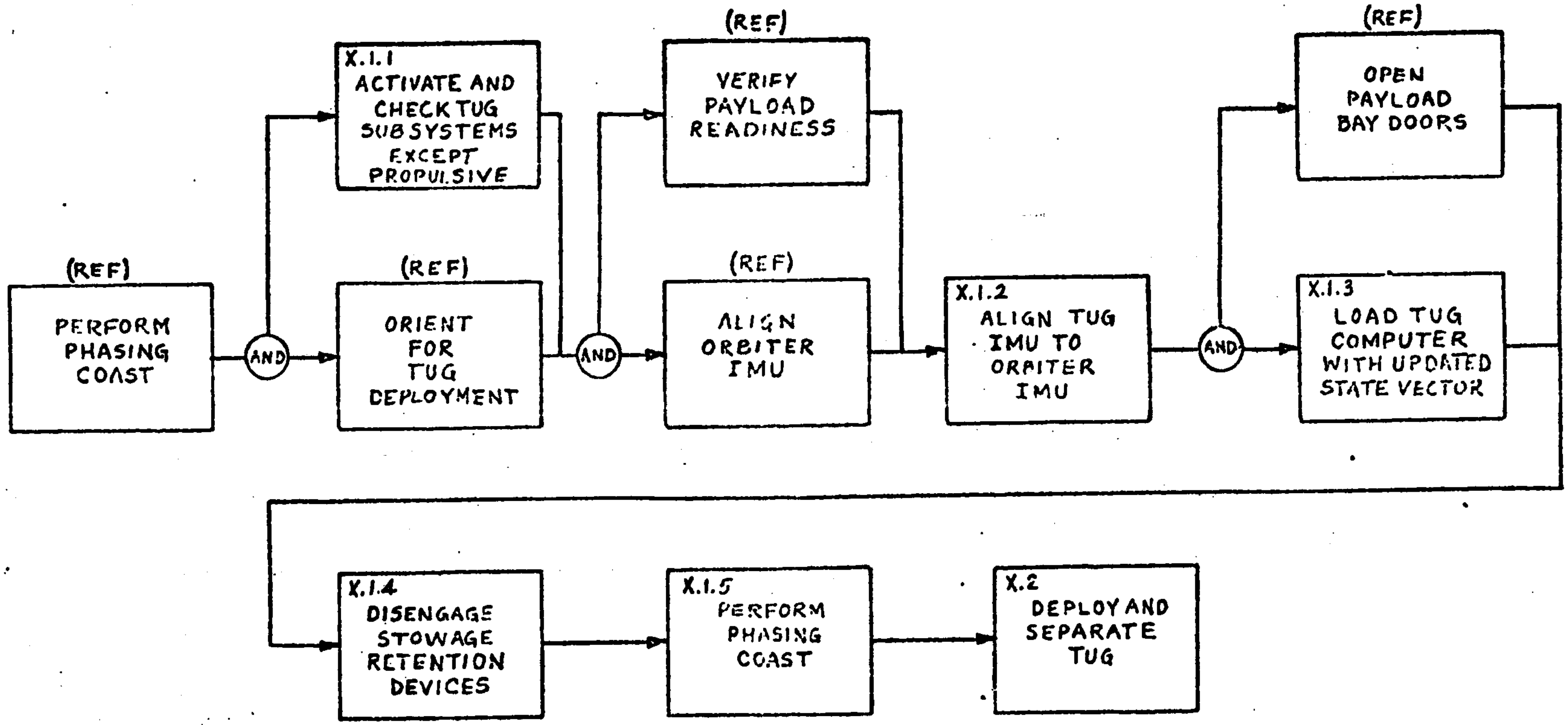


FIRST LEVEL FUNCTIONS

8 REFERENCE MISSION

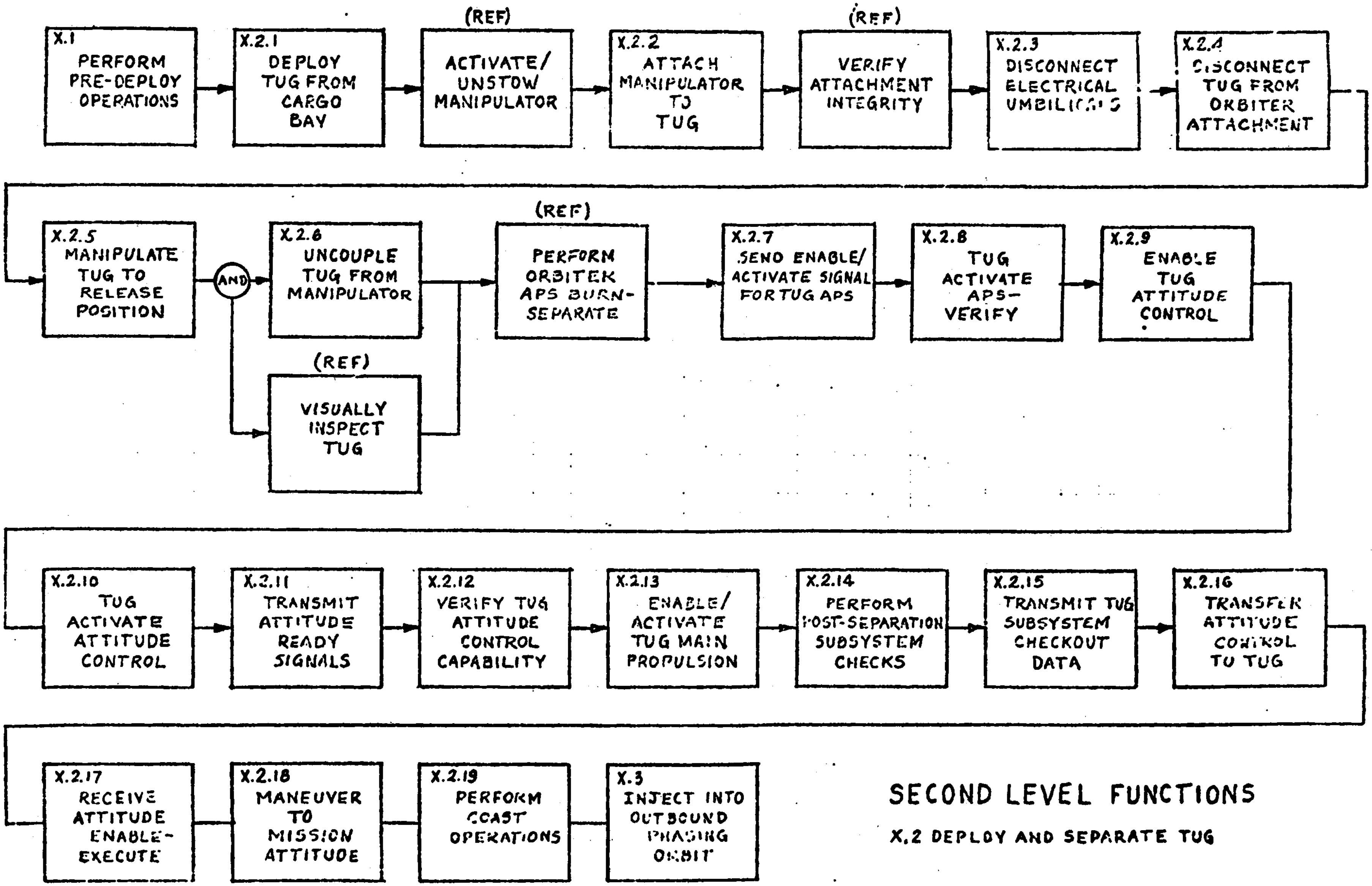
DEPLOYMENT OF SINGLE PAYLOAD

SUN SYNCHRONOUS - LOW POLAR ORBIT



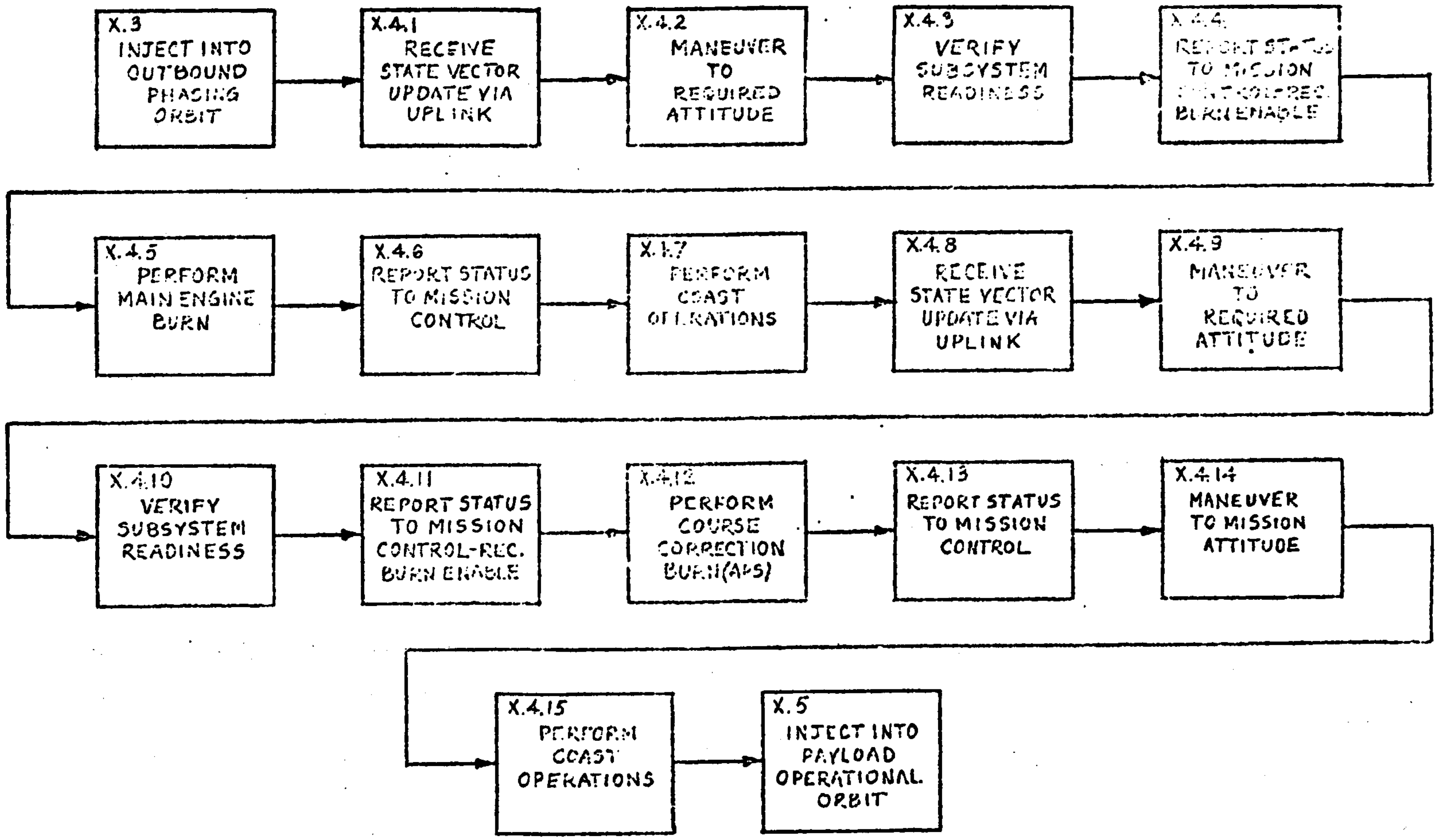
SECOND LEVEL FUNCTIONS

X.1 PERFORM PRE-DEPLOY OPERATIONS



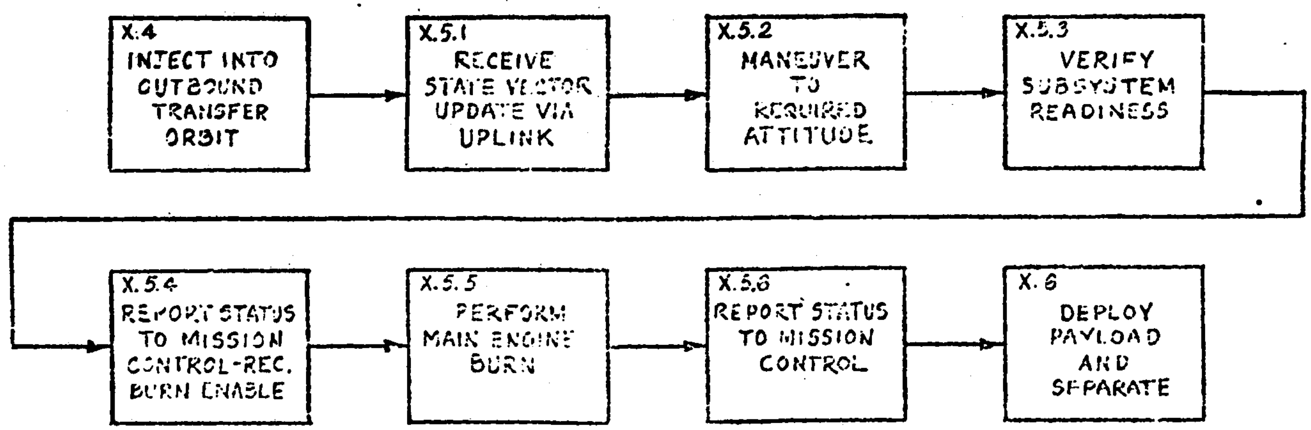
SECOND LEVEL FUNCTIONS

X.2 DEPLOY AND SEPARATE TUG



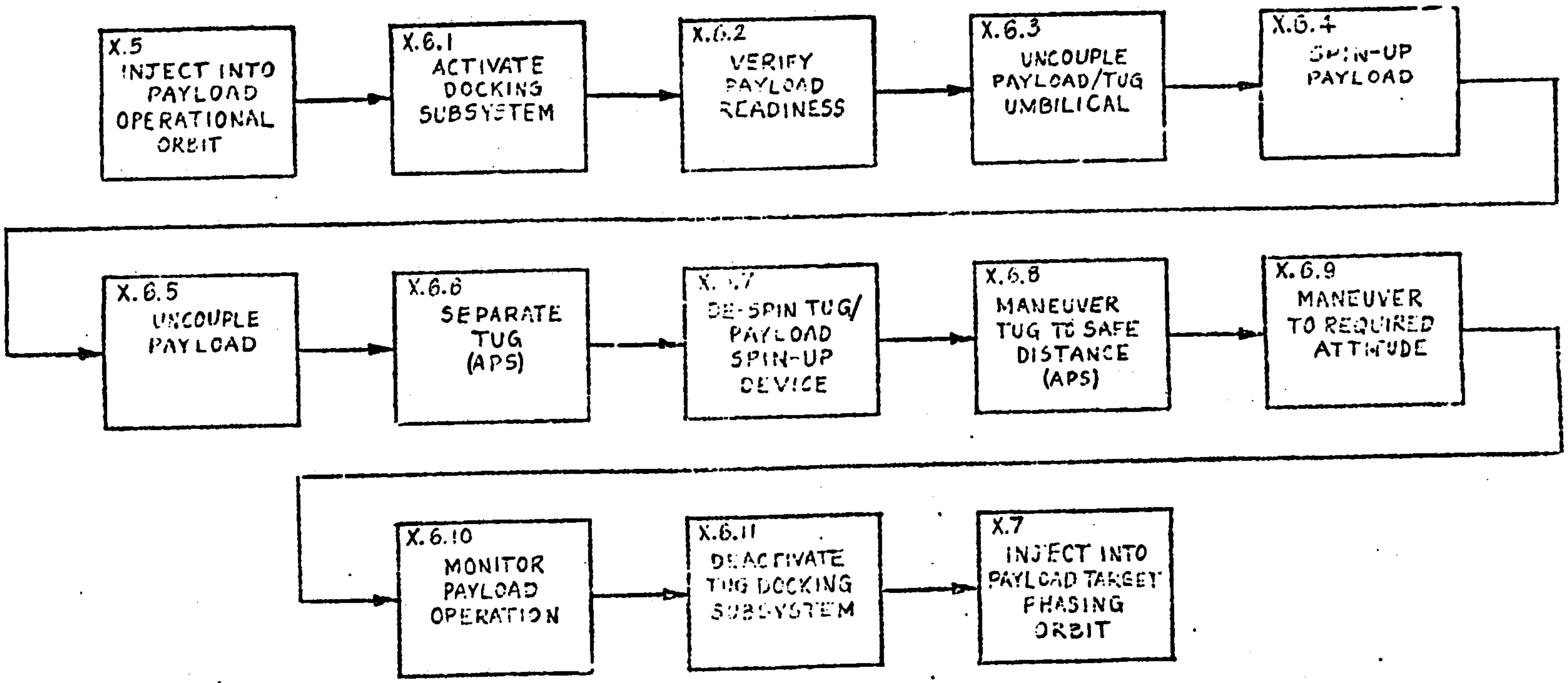
SECOND LEVEL FUNCTIONS

X.4 INJECT INTO OUTBOUND TRANSFER ORBIT



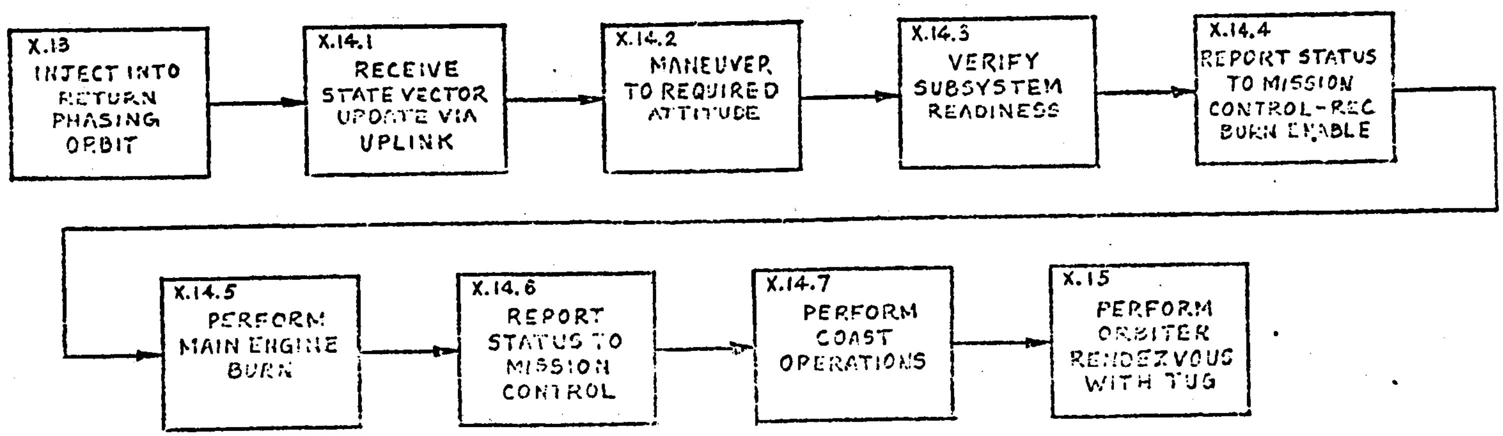
SECOND LEVEL FUNCTIONS

X.5 INJECT INTO PAYLOAD OPERATIONAL ORBIT



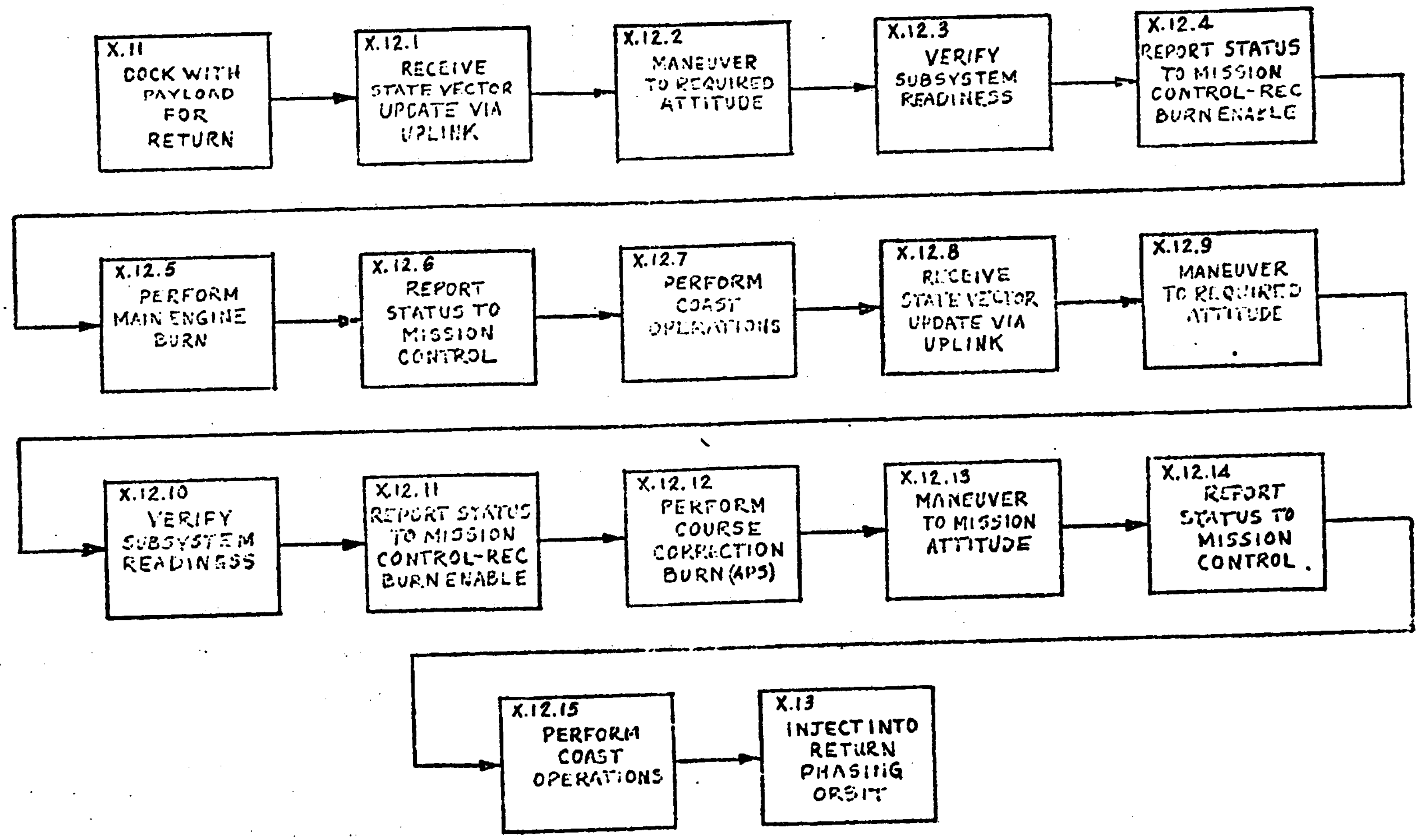
SECOND LEVEL FUNCTIONS

X.6 DEPLOY PAYLOAD AND SEPARATE



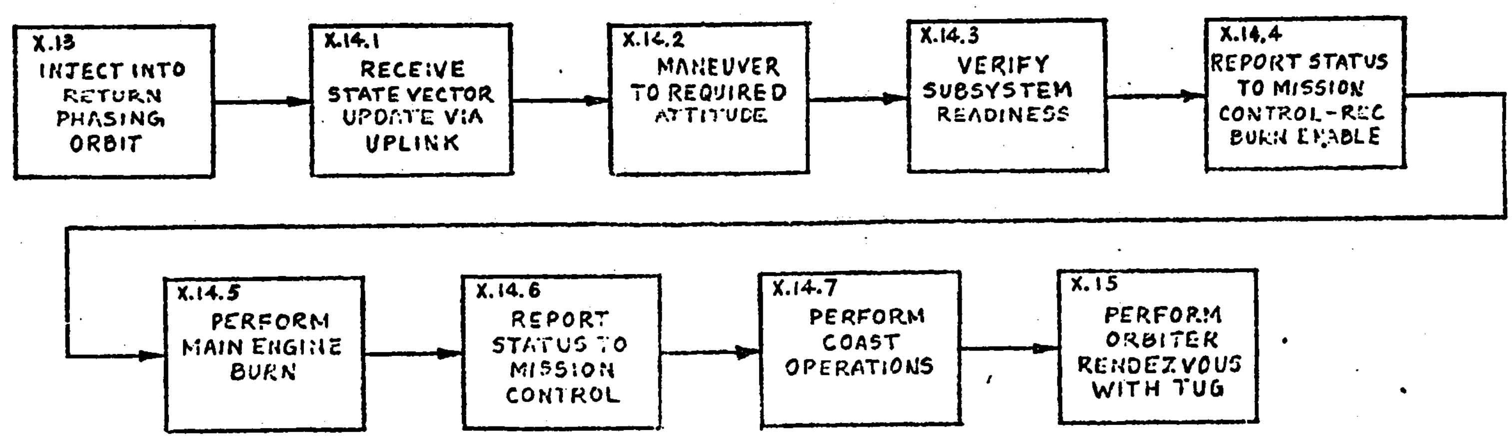
SECOND LEVEL FUNCTIONS

X.14 INJECT INTO ORBITER RENDEZVOUS ORBIT



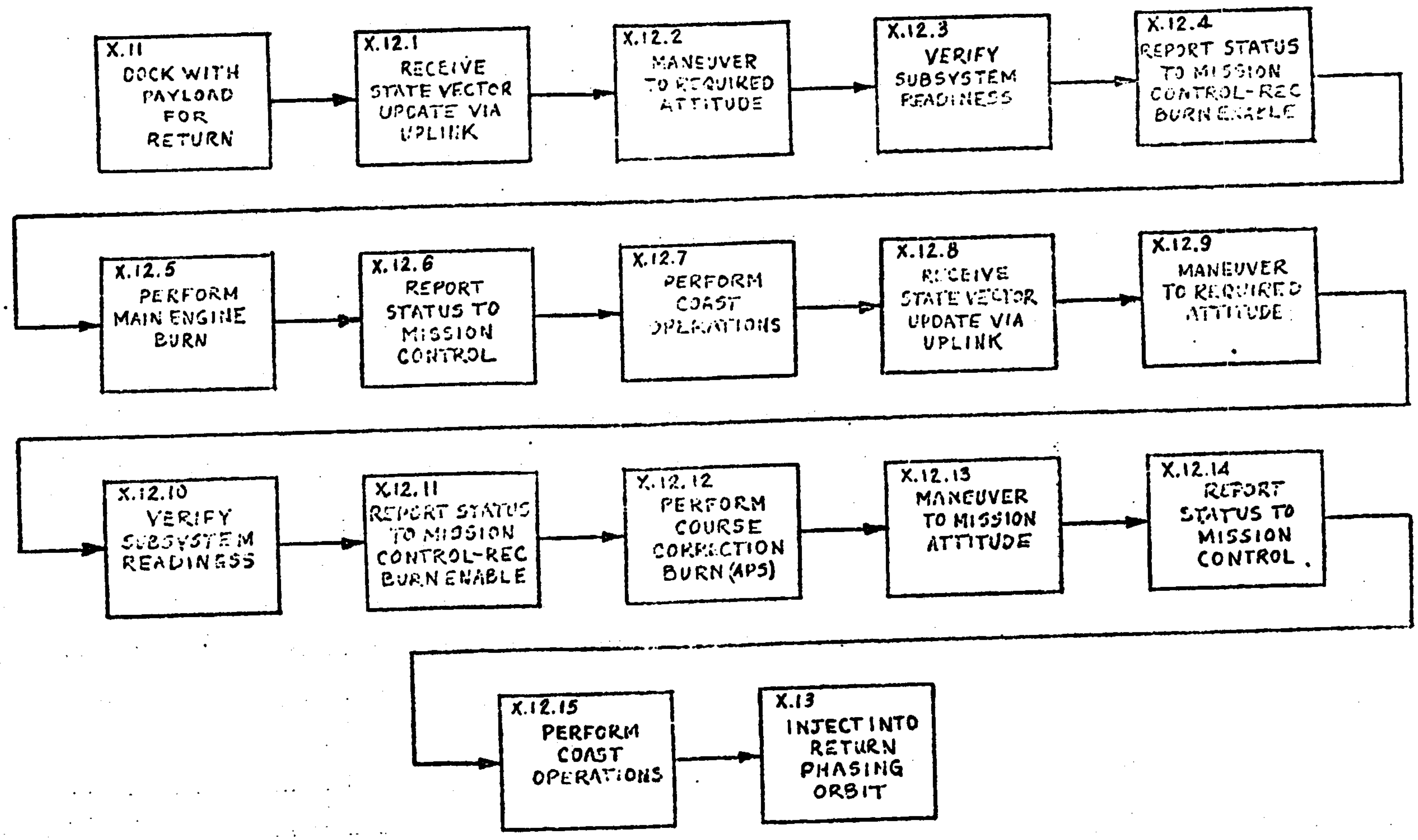
SECOND LEVEL FUNCTIONS

X.12 INJECT INTO RETURN TRANSFER ORBIT



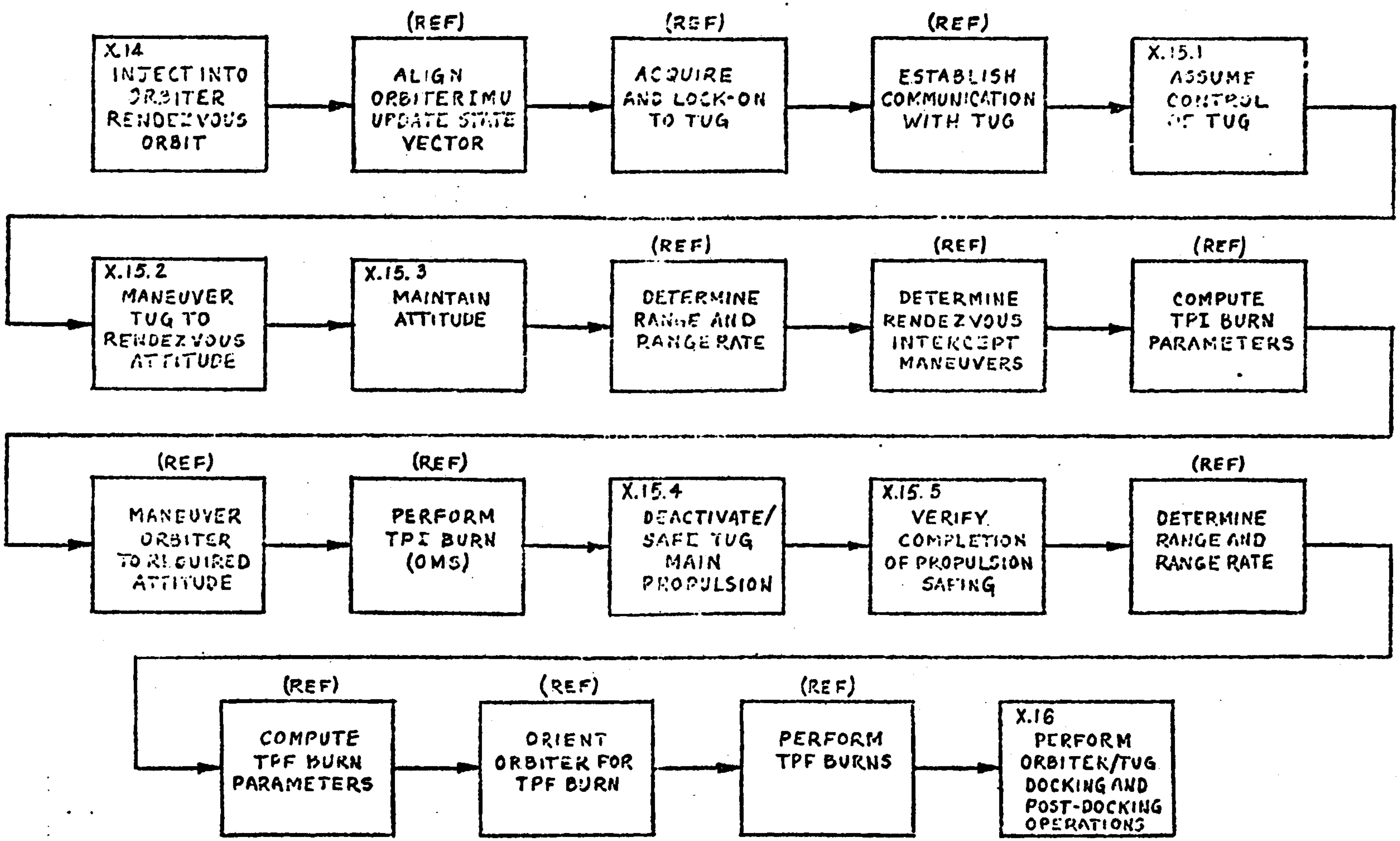
SECOND LEVEL FUNCTIONS

X.14 INJECT INTO ORBITER RENDEZVOUS ORBIT



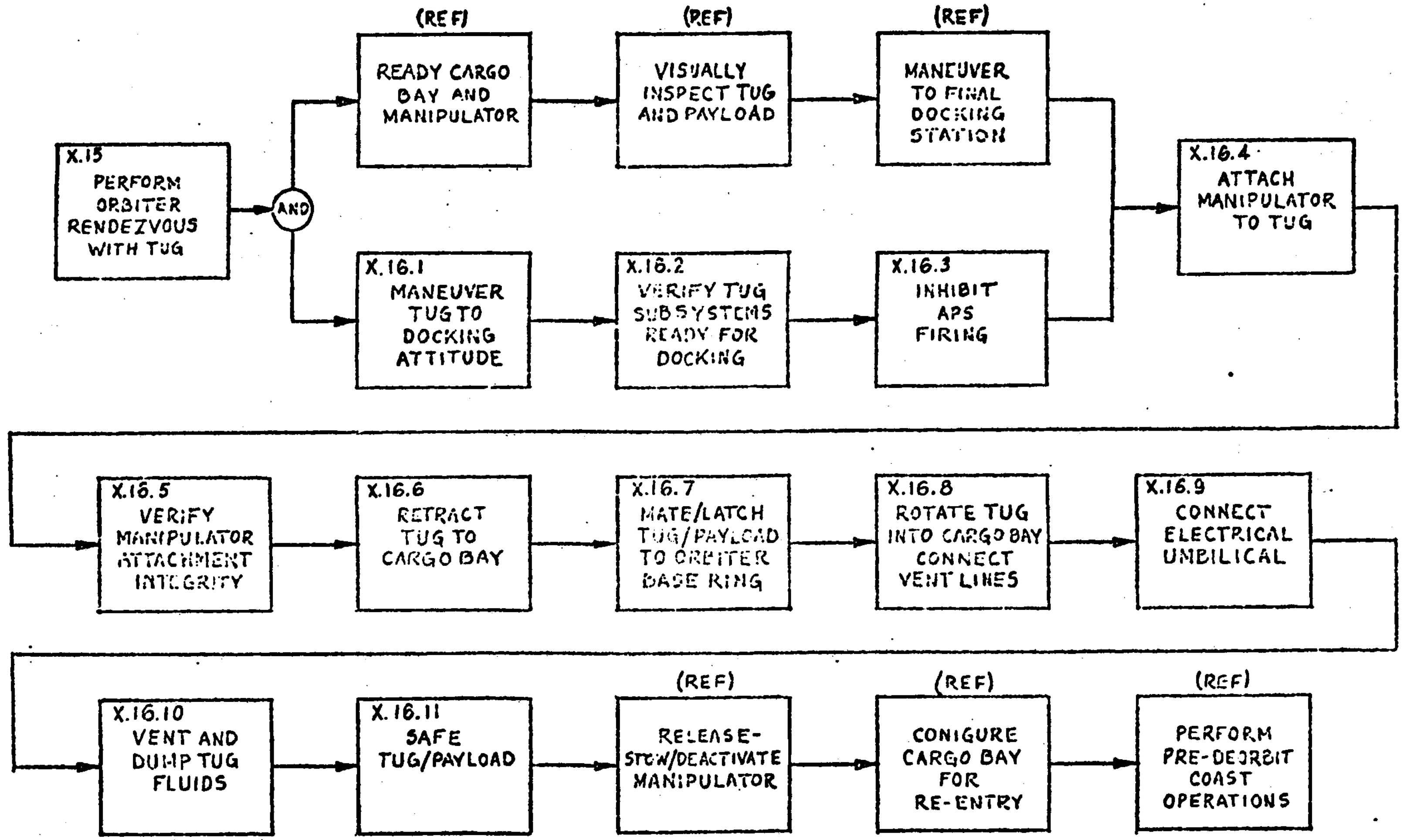
SECOND LEVEL FUNCTIONS

X.12 INJECT INTO RETURN TRANSFER ORBIT



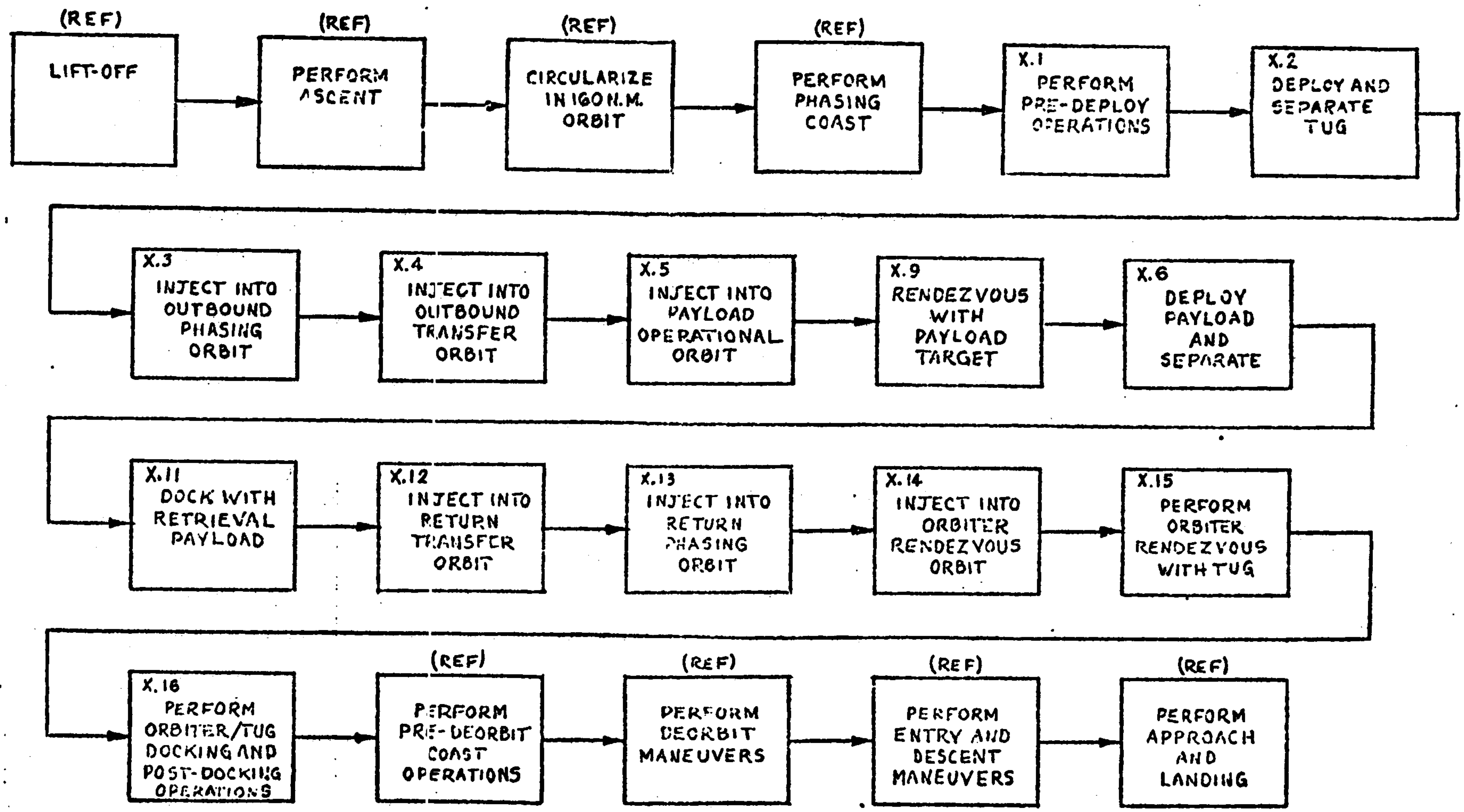
SECOND LEVEL FUNCTIONS

X.15 PERFORM ORBITER RENDEZVOUS WITH TUG



SECOND LEVEL FUNCTIONS

X.16 PERFORM ORBITER/TUG DOCKING AND POST-DOCKING OPERATIONS

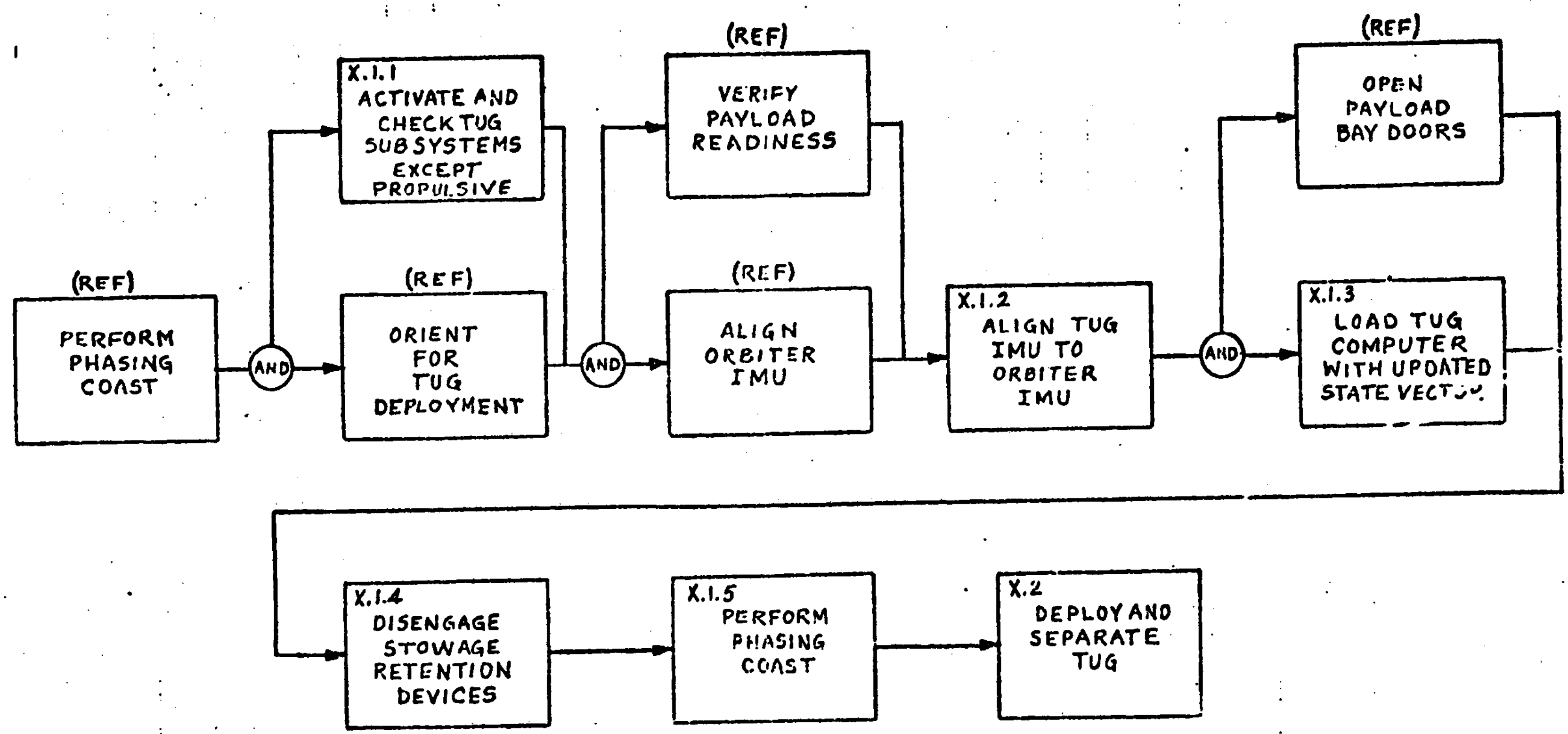


FIRST LEVEL FUNCTIONS

℄ REFERENCE MISSION

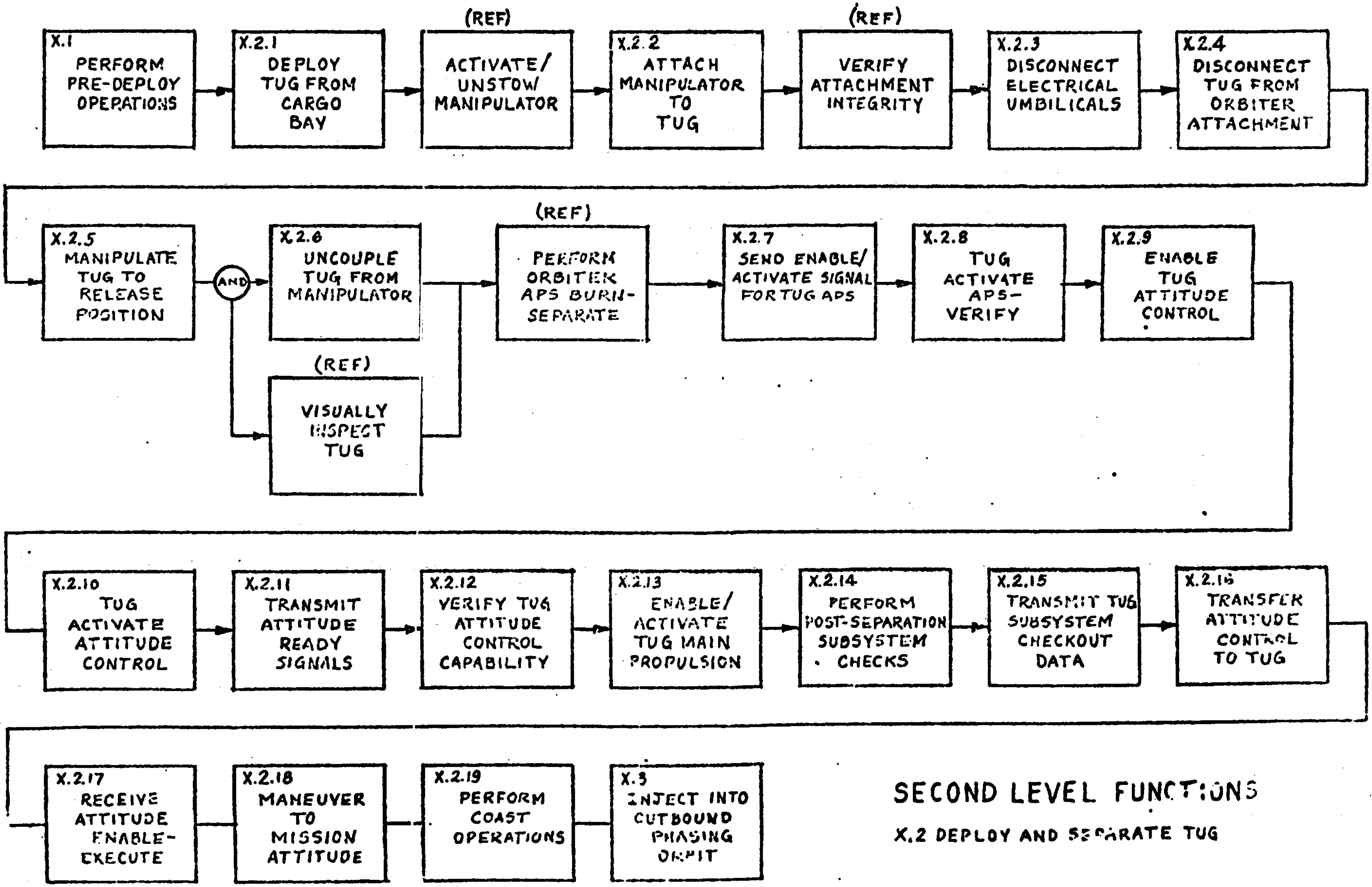
DEPLOYMENT OF ONE PAYLOAD AND RETRIEVAL OF ONE PAYLOAD

HIGH INCLINATION ELLIPTICAL ORBIT



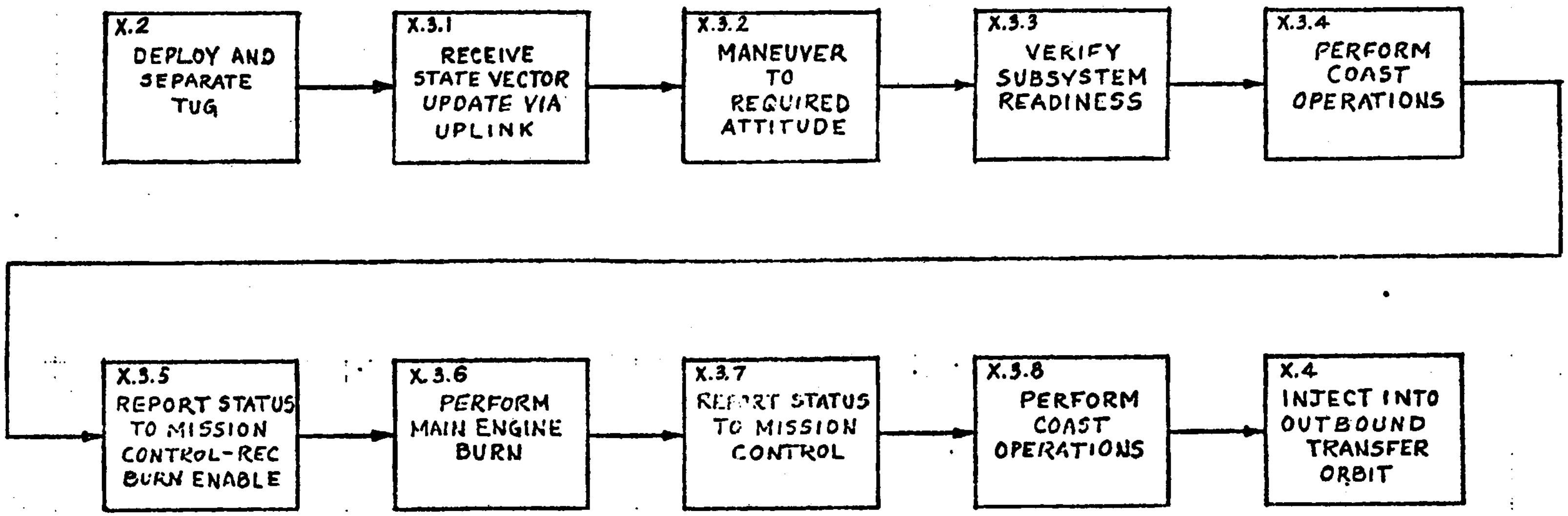
SECOND LEVEL FUNCTIONS

X.1 PERFORM PRE-DEPLOY OPERATIONS



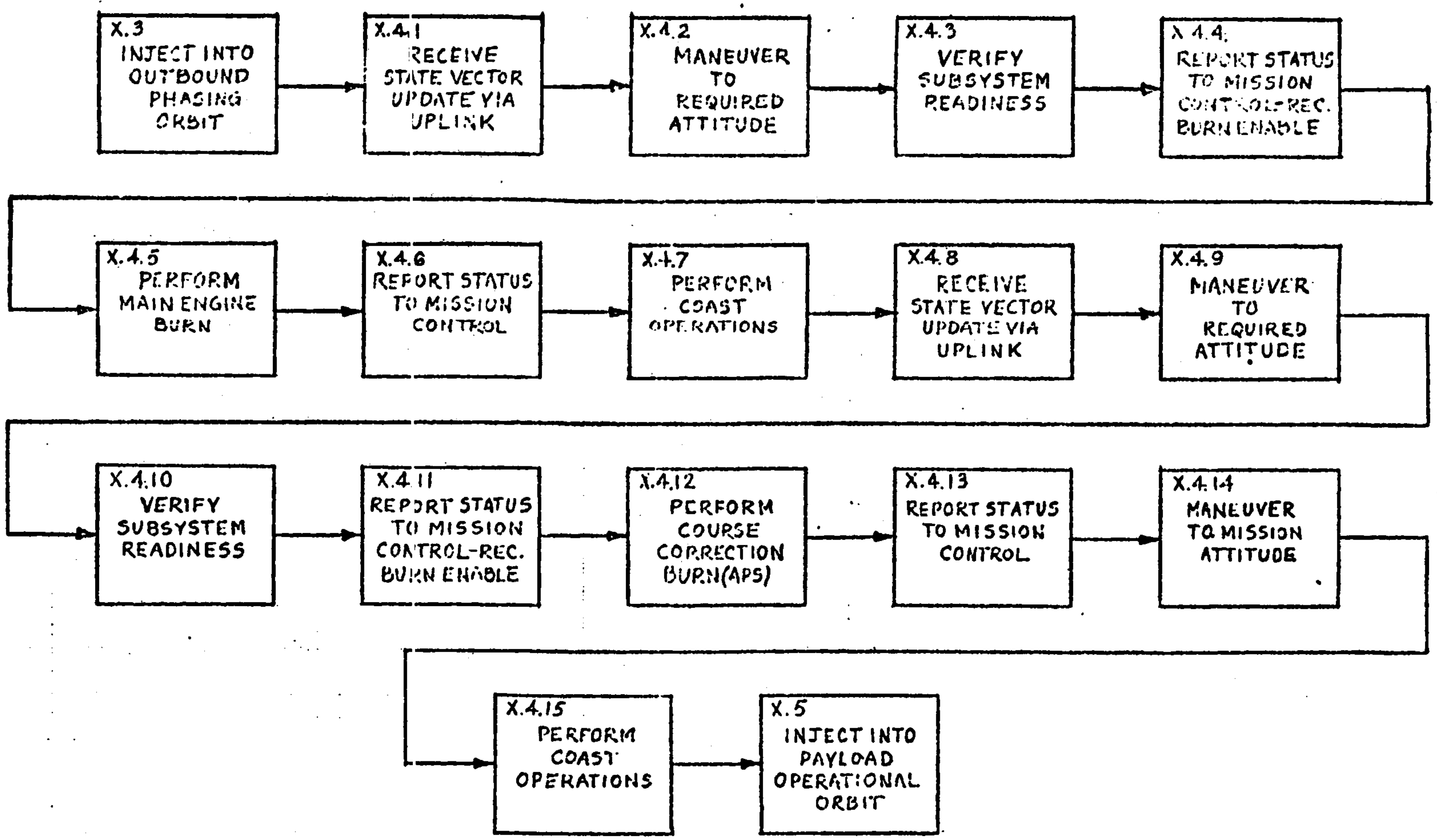
SECOND LEVEL FUNCTIONS

X.2 DEPLOY AND SEPARATE TUG



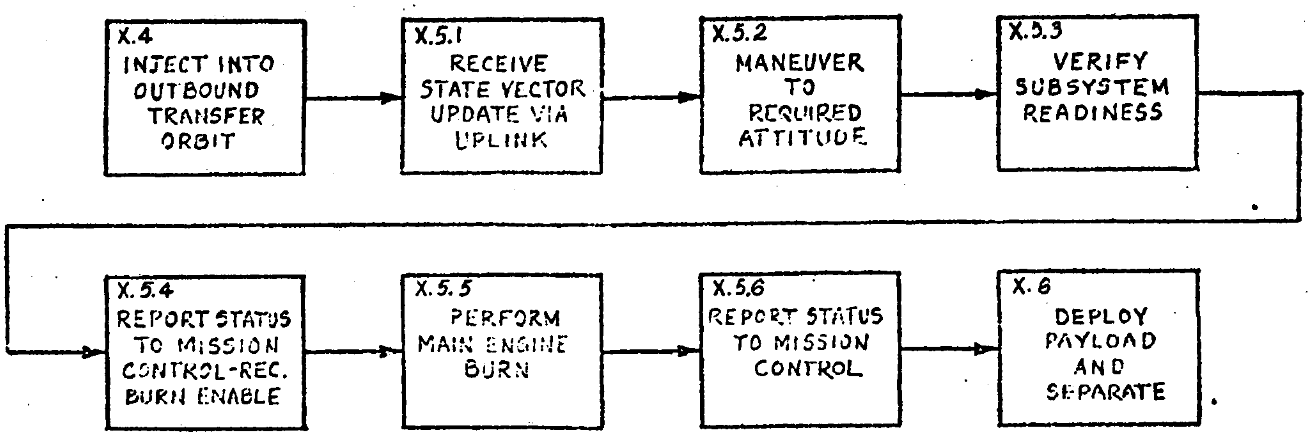
SECOND LEVEL FUNCTIONS

X.3 INJECT INTO OUTBOUND PHASING ORBIT



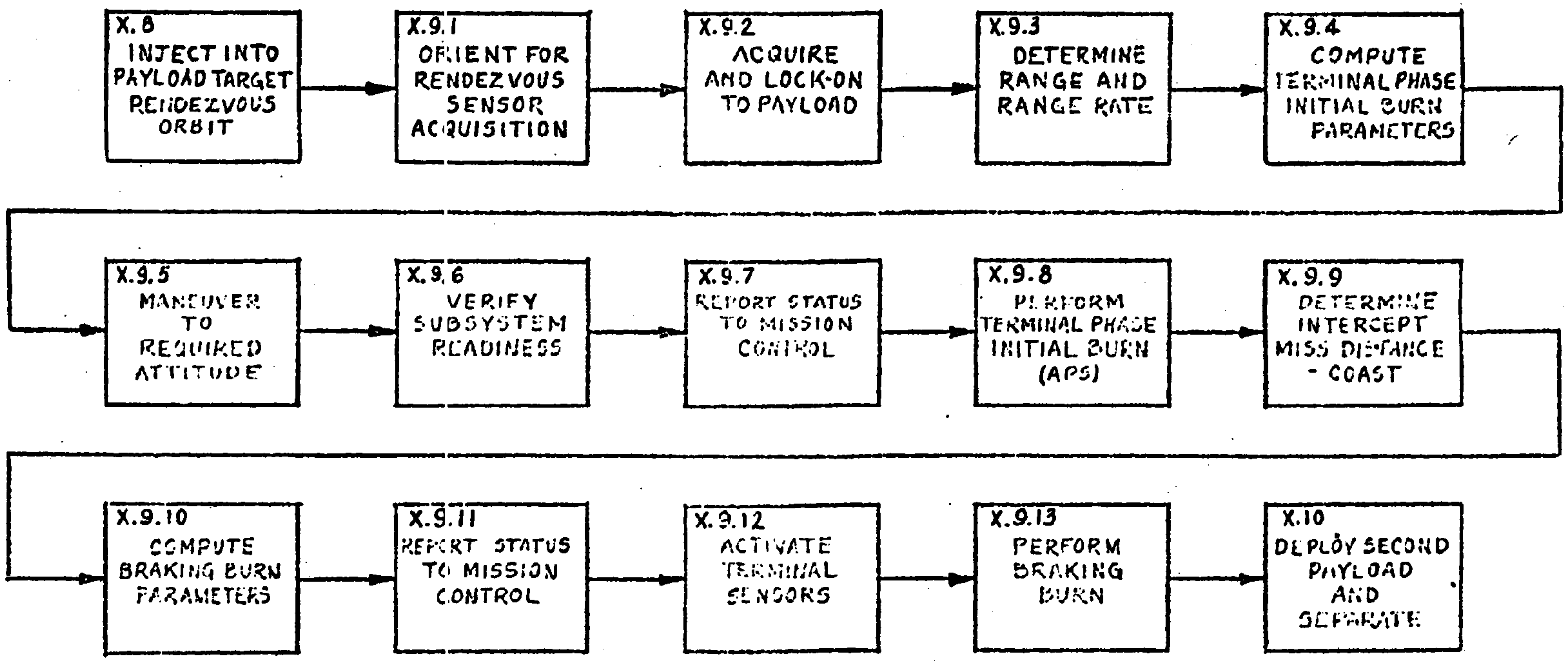
SECOND LEVEL FUNCTIONS

X.4 INJECT INTO OUTBOUND TRANSFER ORBIT



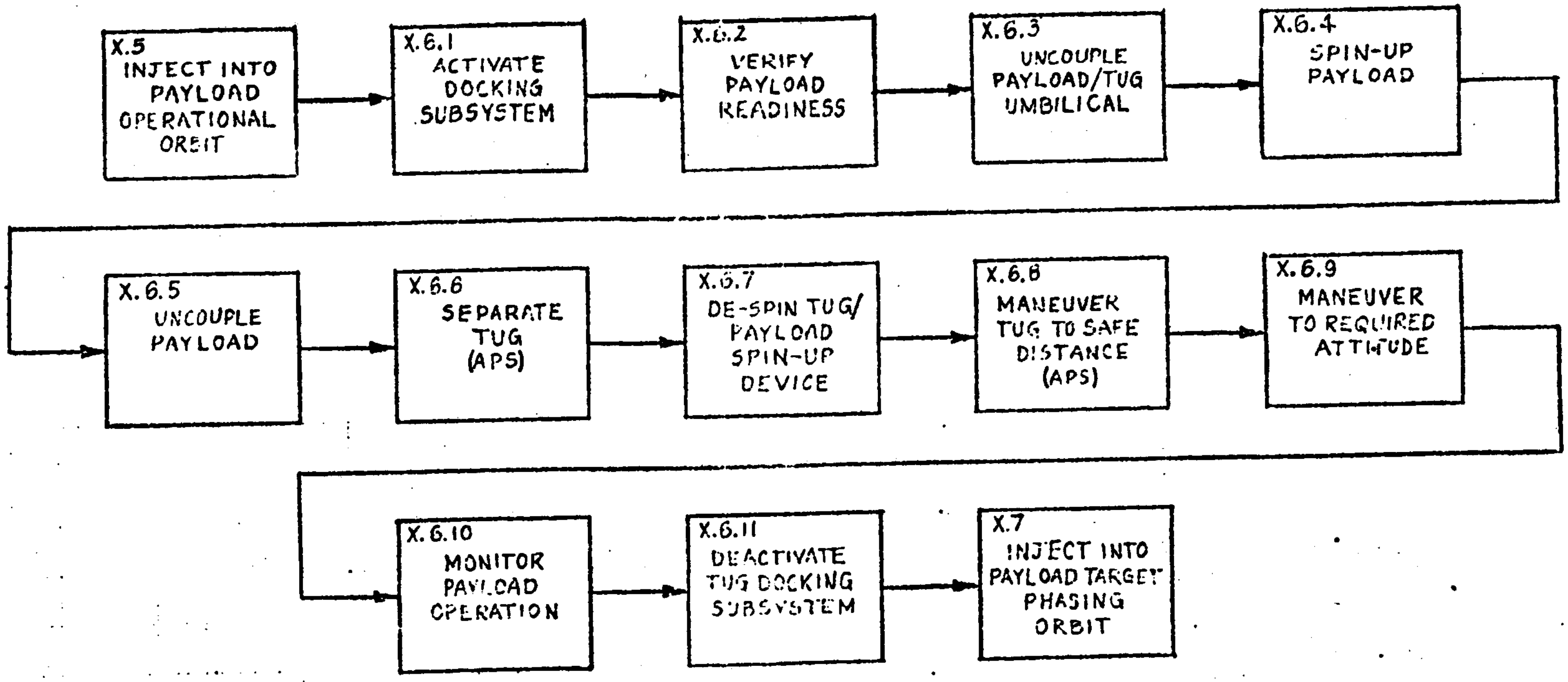
SECOND LEVEL FUNCTIONS

X.5 INJECT INTO PAYLOAD OPERATIONAL ORBIT



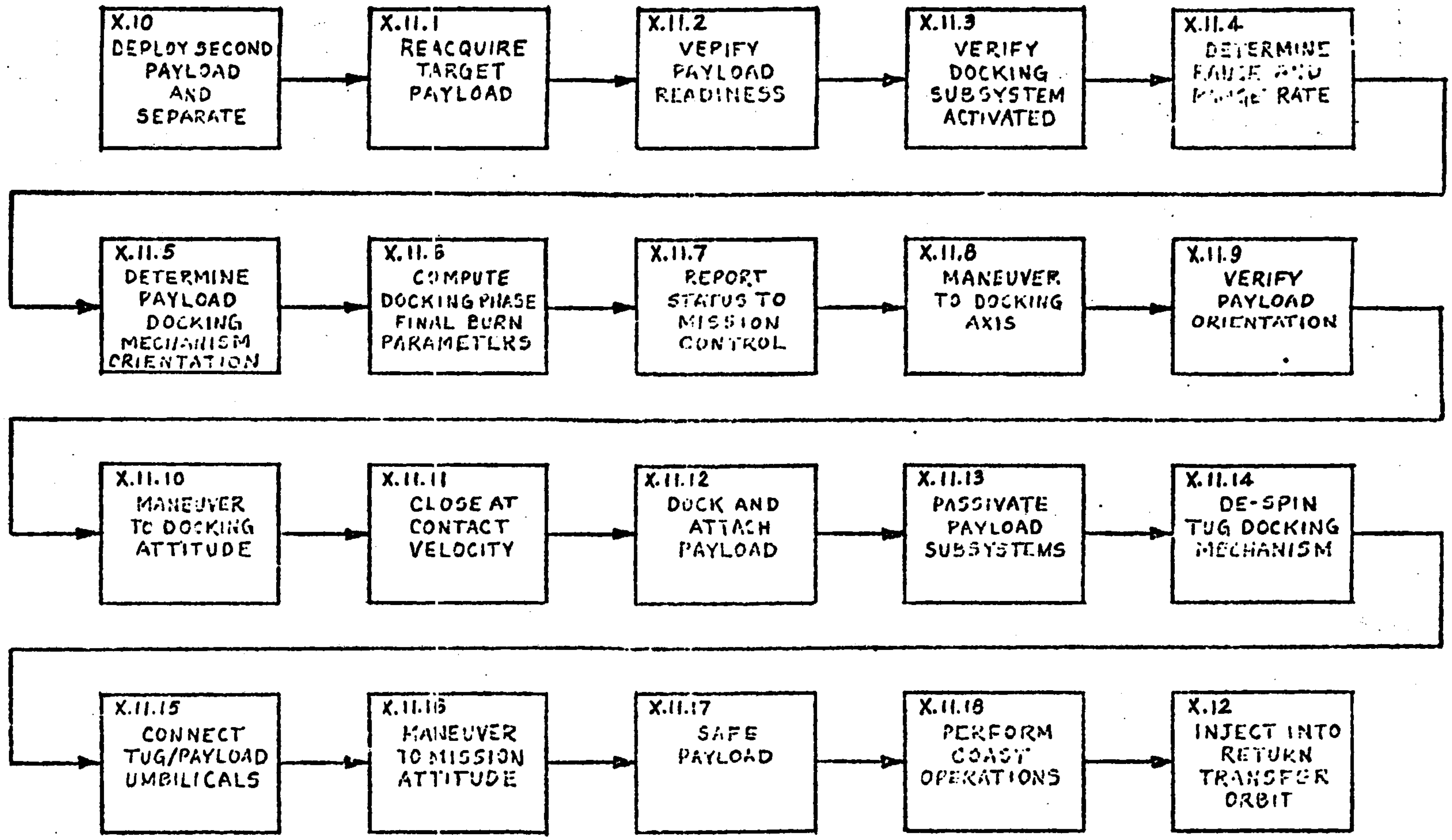
SECOND LEVEL FUNCTIONS

X.9 RENDEZVOUS WITH PAYLOAD TARGET



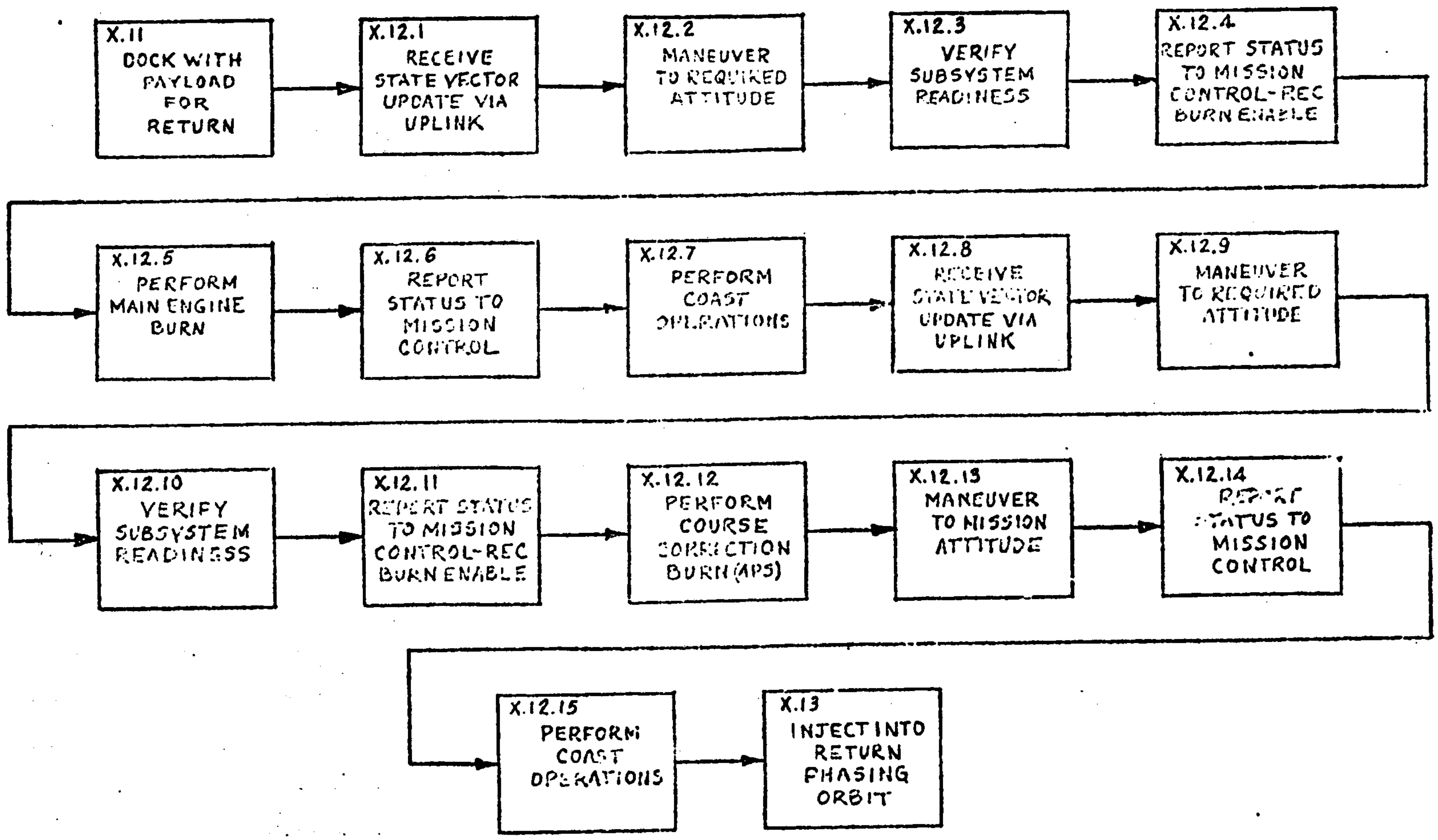
SECOND LEVEL FUNCTIONS

X.6 DEPLOY PAYLOAD AND SEPARATE



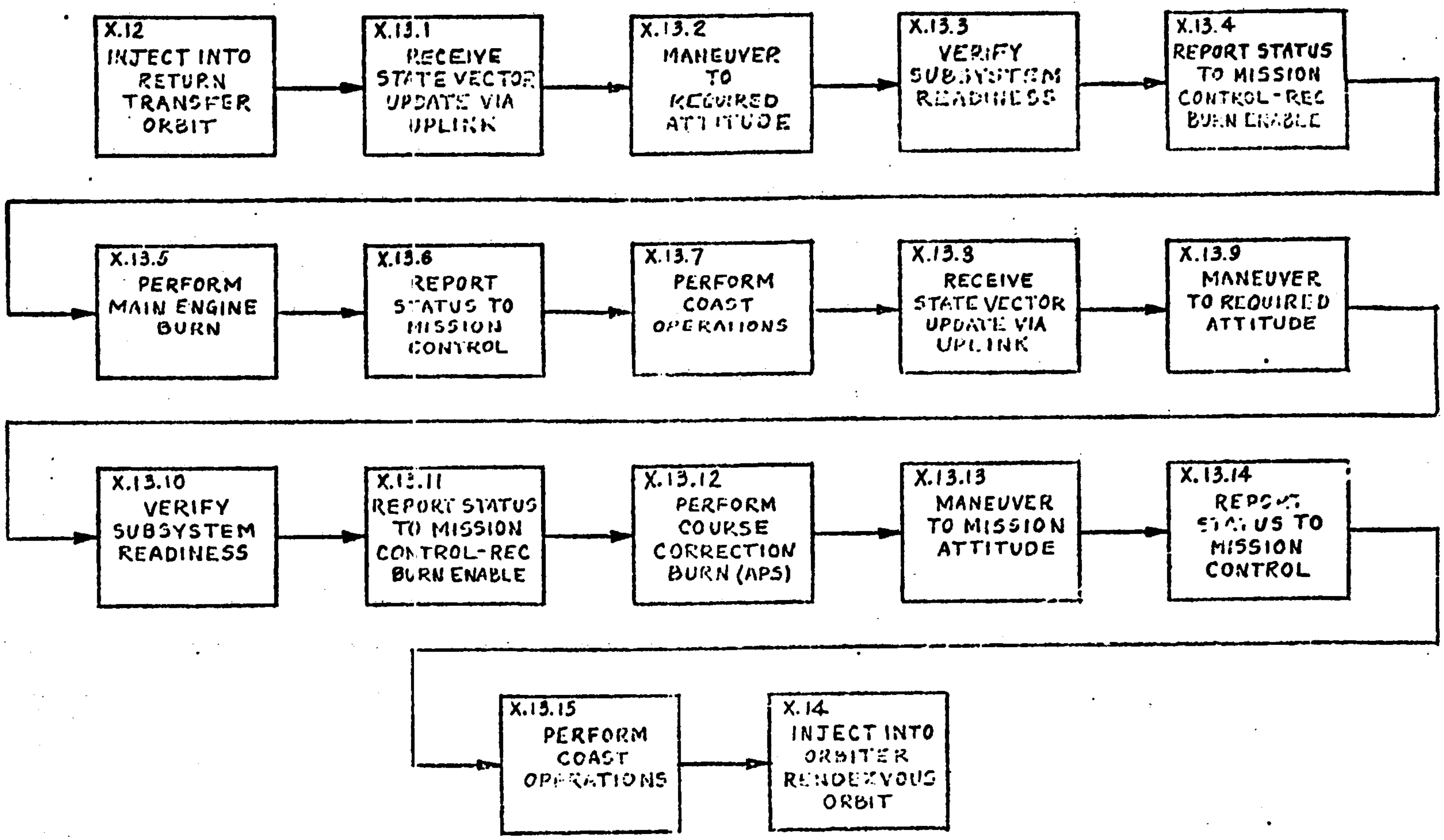
SECOND LEVEL FUNCTIONS

X.11 DOCK WITH PAYLOAD FOR RETURN



SECOND LEVEL FUNCTIONS

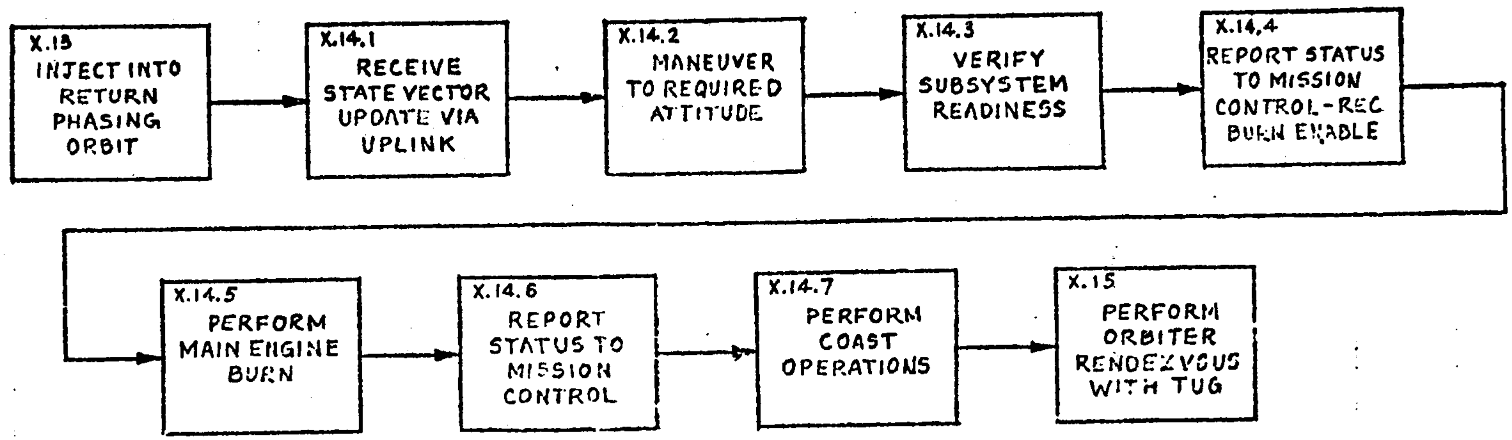
X.12 INJECT INTO RETURN TRANSFER ORBIT



SECOND LEVEL FUNCTIONS

X.13 INJECT INTO RETURN PHASING ORBIT

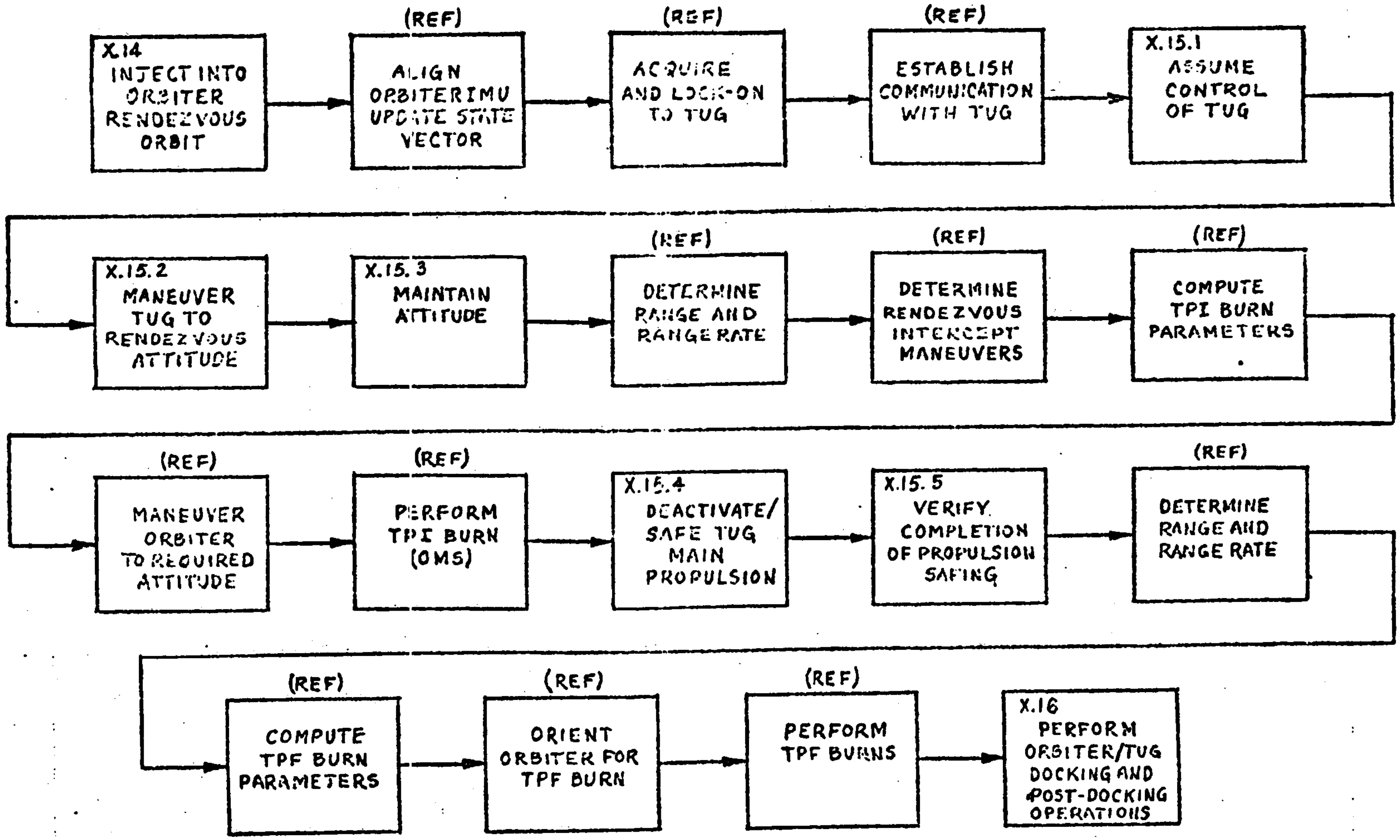
DOUGLAS



SECOND LEVEL FUNCTIONS

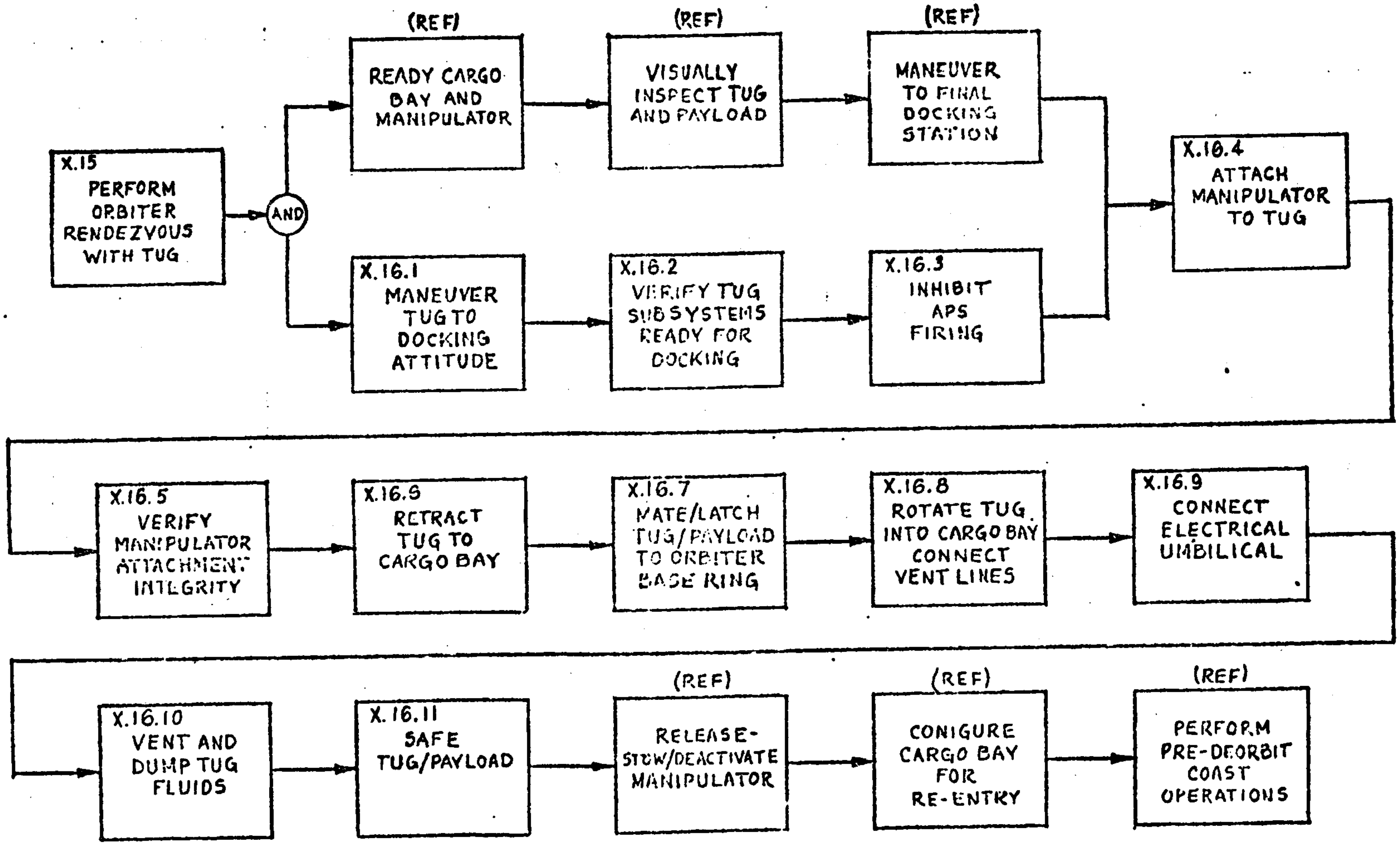
X.14 INJECT INTO ORBITER RENDEZVOUS ORBIT

DOUGLAS



SECOND LEVEL FUNCTIONS

X.15 PERFORM ORBITER RENDEZVOUS WITH TUG

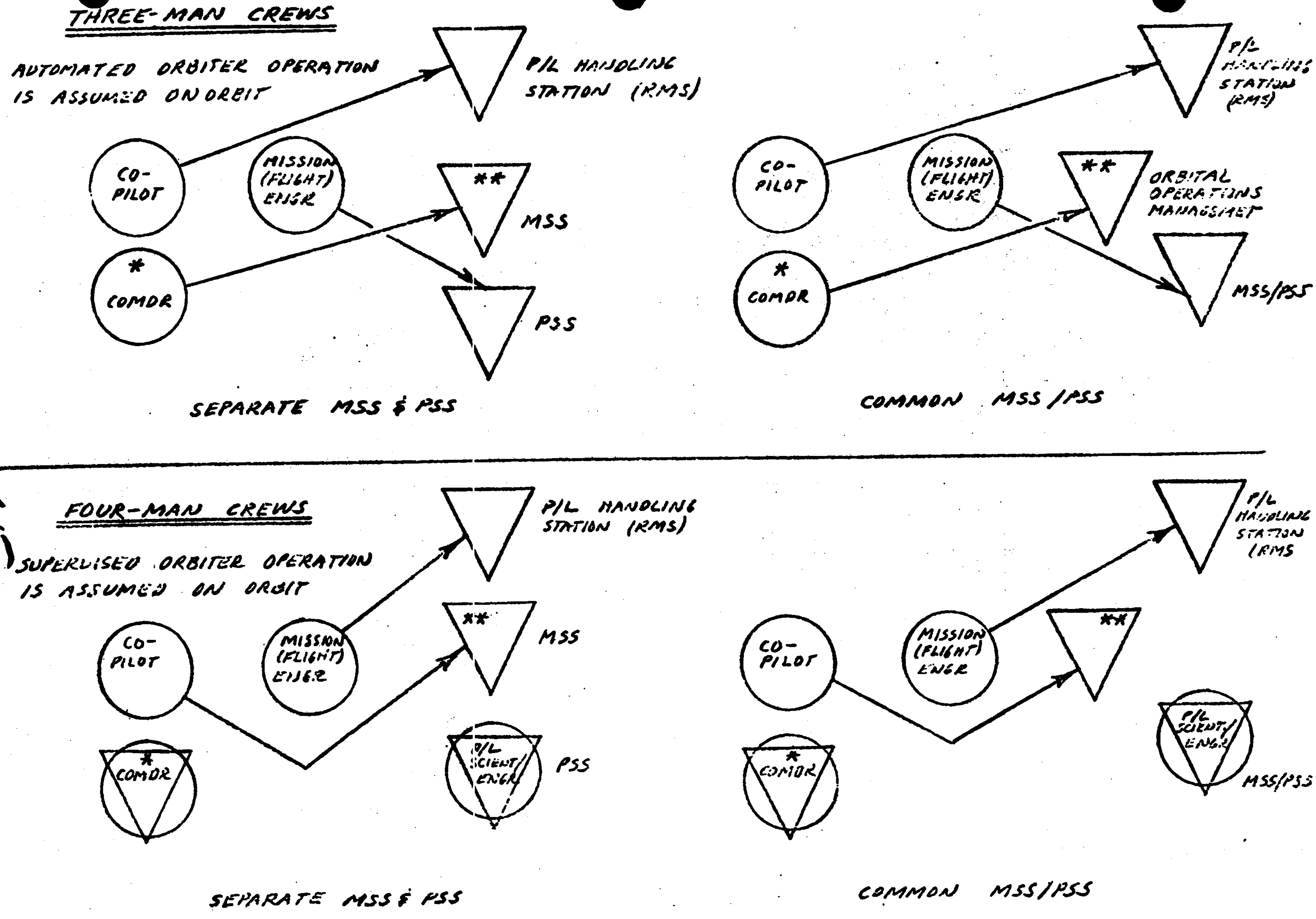


SECOND LEVEL FUNCTIONS

X.16 PERFORM ORBITER/TUG DOCKING AND POST-DOCKING OPERATIONS

Figure 5.2-2

CREW STATION OPTIONS



* COMMAND STATION FOR LAUNCH, FLIGHT, AND RECOVERY

** MISSION [illegible] IS MANAGEMENT STATION FOR ORBITAL OPERATIONS

CREW-SIZE IMPACT ASSESSMENT - I

<u>One-Man Crew</u>

(Totally Impractical)

<u>Two-Man Crew</u> (Difficult to impossible without highly automated systems)

If Autopilot operation of Orbiter is provided:

- Provide Orbiter C&W panel at mission specialist station
- Commander can operate mission specialist station
- Copilot can operate payload handling (RMS) station
- Payload monitoring, orbital readiness testing (health checks) are assumed to be Tug autonomous or performed by remote monitoring from the ground
- This mode is very demanding and may not be compatible with an unsophisticated payload with less autonomy incorporated for self-activation and management

<u>Three-Man Crew</u> (Practical minimum crew)

Similar to two-man crew in many respects.

- Autopilot operation of Orbiter is assumed
- Orbiter C&W panel is provided at MSS
- Commander provides overall supervision of all orbiter, Tug, and payload C&W monitoring, safety activities, and other operations; including communications with the ground and procedural document check off.
- Copilot operates payload handling (RMS) station as directed and maintains visual contact with the payload bay and contained hardware.
- Mission engineer/scientist operates combined MSS/PSS, including manual activation, monitoring and payload-related ground communications.
- Commander is available as backup to assist either of the other two crewmen (who are essentially immobilized by their duties). He can also respond to an orbiter emergency or caution signal without interfering with a possibly critical phase of payload deployment or retrieval.

CREW-SIZE IMPACT ASSESSMENT - II

Other Factors

- Orbiter station provisions for other mission models will influence Tug missions because hardware/software will:
  1. Be available anyway as required for other missions.
  2. Shape the standard operating techniques of the crew.
  3. Influence the division of duties between stations via physical separation of equipment.
- Fourth man can be derived from other missions (Sortielab)
- Prelaunch operations by the crew when both Orbiter and Tug/payload activities are involved (same for reentry) will be time-constraining.
- Complexity and/or extensive manual support by the crew of some payloads (now in mission model or potential for future addition). Mission flexibility for future added missions and for mission extension may dictate other than a minimum crew capability for the Orbiter.
- Orbital readiness testing of payloads is a key driver, particularly with continuous activity but intermittent ground station passes. Calibration of complex channels and de-gassing time lost for high voltage equipment have been identified, and real-time data verification or analysis will require crew time and skills. While these could be passed to the ground, acted upon and control directives be sent back up; the times over truth sites, time to communicate, time to command new data acquisition and time before again passing over truth sites will impose operational complexities and constraints. This suggests more available crew time and skills.
- Many safety-related activities (passivation, stabilization, purging, de-activation) for Tug and payloads; plus Tug maneuvering, Orbiter maneuvering, RMS operation, Tug support hardware operation, and Tug monitoring functions occur during Tug/payload retrieval.
- SOAR II-S study mid-term (July 1973) conclusion: "Insufficient time exists for all payload subsystems to be checked out at MSS. Therefore it is recommended that Tug and Orbiter performance and checkout be performed at the MSS and that spacecraft systems as well as experiments be handled by the PSS."

- Provides better management during launch, abort, and return flight when both commander and copilot are fully occupied with Orbiter flight duties

Four-Man Crew (Provides ample manpower with less operational constraints)

- Manual supervision of the Orbiter by the commander is assumed.
- Copilot assumes active supervision of payload operations with functions similar to those of the commander described for a three-man crew. He may operate a separate MSS.
- Mission engineer operates payload handling (RMS) station
- Payload scientist/engineer operates a common MSS/PSS, or he operates the separate PSS.
- Provides more skills and better timeline potential for off-duty time.

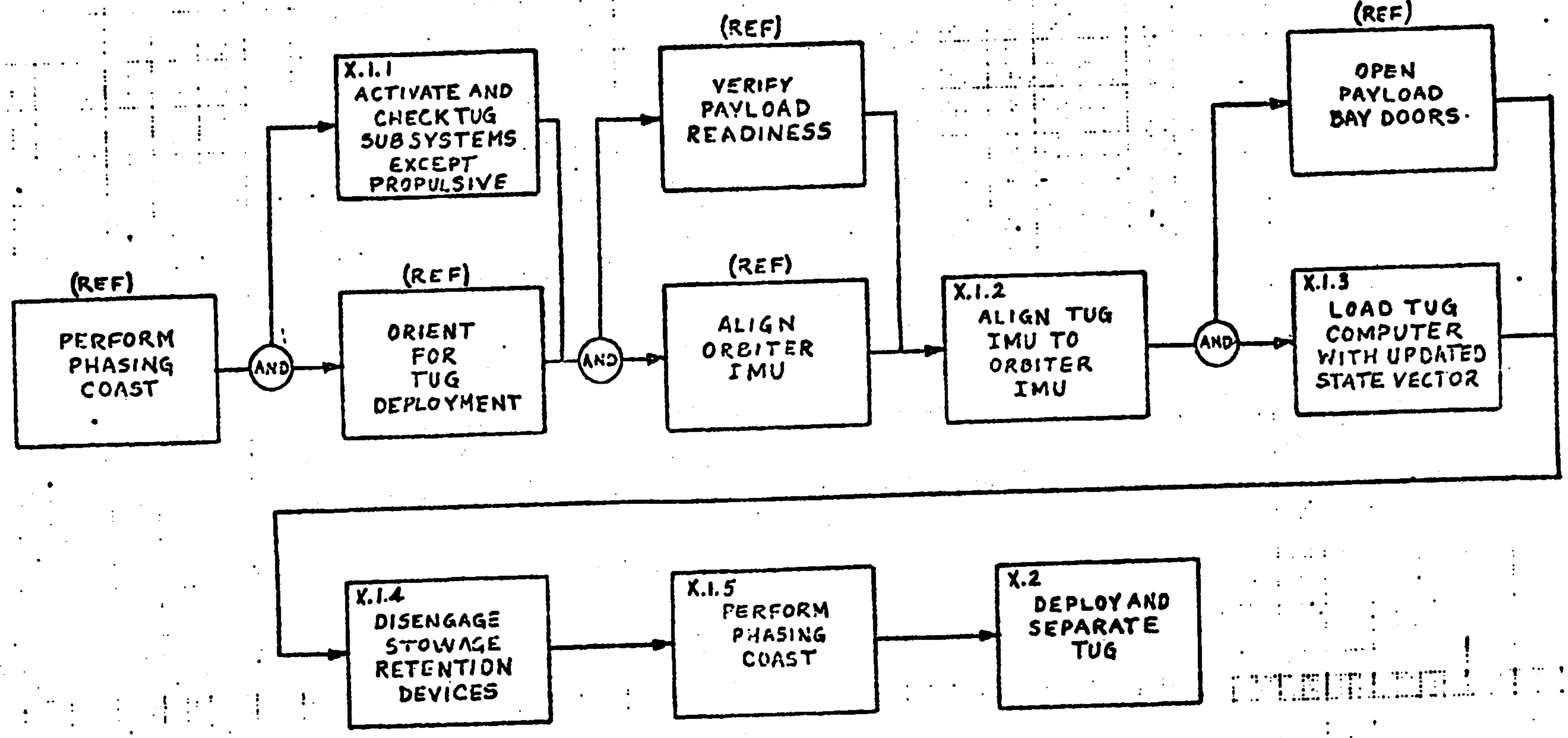
capability, and total crew-skills will be available from a four-man crew. The four-man crew also allows rest or sleep periods for extended and combination missions; and it allows for commonality of equipment, training, and operational procedures between short Tug deployment or retrieval missions and the seven-day Sortie Lab missions, for example.

Additional insight for crew functions is provided by the Second-Level Function charts, Figures 5.2-3 through 5.2-6. Additional information, functional flow charts, and operational concepts are provided in Section 6.2.2 for the complete missions.

5.3 Computer Requirements

The Tug subsystems are monitored, activated, and checked out through the Tug Data Management System as described in Volume 5, Section 5.4.2.3. The avionics interfaces include a Tug-unique panel section on the Mission Specialist Station (MSS) panel. These dedicated elements provide a capability to access the Tug subsystems data and to convert it for input to the Orbiter computer and/or the payload computer (these may be combined physically or functionally). The Tug data may be displayed directly on the Tug-unique Control and Display panel, or it may be processed by the Analog/Digital Converter/Multiplexer and transferred to the Shuttle Payload Computer for display on the Orbiter Performance Monitor Panel at the MSS.

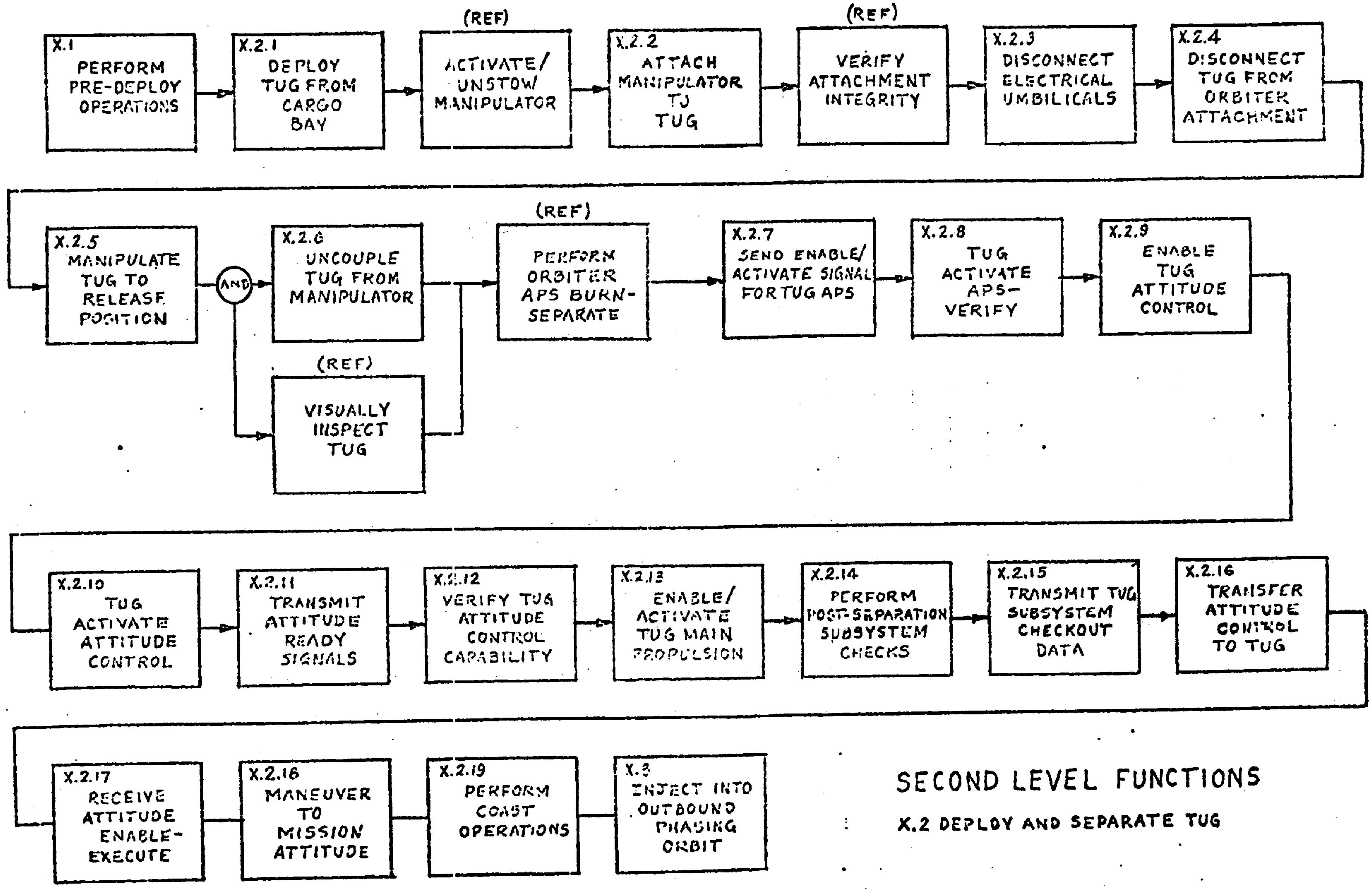
Control functions which are necessary to correct for caution and warning signals and conditions are provided on the Tug unique Control and Display panel at the MSS. These may operate either directly upon the affected Tug subsystem circuitry or may utilize Shuttle Payload computer or Tug internal computer capabilities. The preference will be to utilize the Tug computer for all computer services which are available to autonomously manage the same function after Tug deployment.



SECOND LEVEL FUNCTIONS

X.1 PERFORM PRE-DEPLOY OPERATIONS

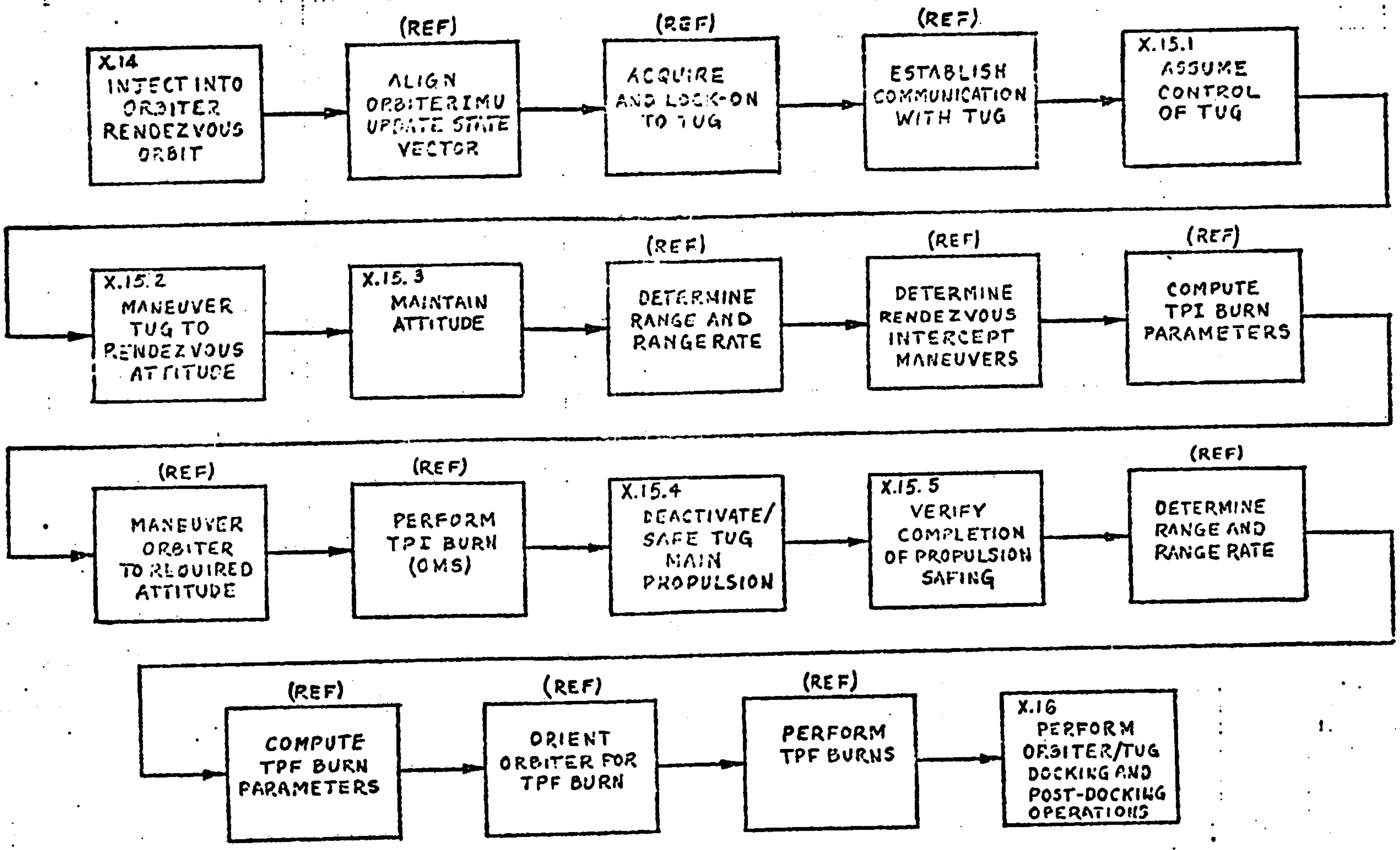
Figure 5.2-3 4 3



SECOND LEVEL FUNCTIONS

X.2 DEPLOY AND SEPARATE TUG

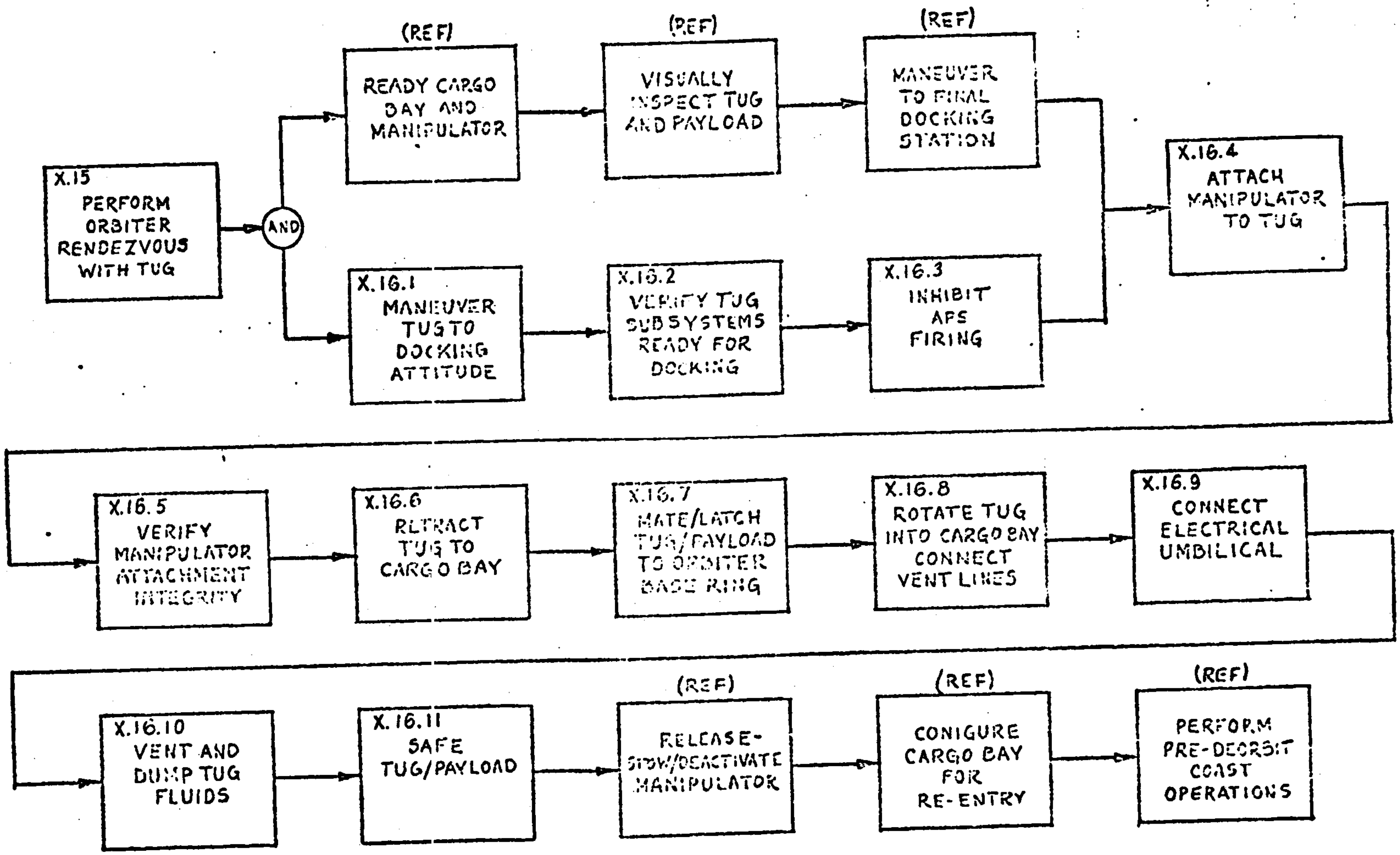
Figure 5.2-4



SECOND LEVEL FUNCTIONS

X.15 PERFORM ORBITER RENDEZVOUS WITH TUG

Figure 5.2-5



SECOND LEVEL FUNCTIONS

X.16 PERFORM ORBITER/TUG DOCKING AND POST-DOCKING OPERATIONS

1. 6

Figure 5.2-6

The specific bit rate requirements are shown in Volume 5, Section 5.4.2.3 for the Shuttle/Tug interface as follows:

	Orbiter to Tug	Tug to Orbiter
NASA Communications	2,000 BPS (Data and Time Multiplex Commands)	25,000 BPS (Tug/Payload Status Data and Command Verfication)
DOD Communications	2,000 BPS (Secure Command Data)	16,000 BPS (Tug/Payload Status Data and Command Verification)
	16,000 BPS (Program Modifying Data)	256,000 BPS (Payload Secure Data)
		FM/FM IRIG Payload Analog Instrumentation Data

6.0 ABORT ANALYSIS

An abort analysis was conducted to assess the merits, liabilities and relative impacts of (1) landing with full LO_2 and LH_2 tanks, (2) dumping LO_2 only, (3) dumping both LO_2 and LH_2 in sequence, and (4) dumping both LO_2 and LH_2 simultaneously. Abort from both suborbital (Mode III) and orbital (Mode IV, V and VI) were analyzed. These options are discussed in detail as part of the trade studies reported in Section 12.6, covering land full versus dumping options. The results of these analyses are reported in the abort analysis summary, Section 2.5.

The abort analysis discussed below includes:

(6.1) a detailed sequence list and timeline of the events associated with cryogen dumping;

(6.2) the Shuttle requirements to be satisfied during the dumping sequence;

(6.3) the flight altitude and time of dumping events versus the dumping sequence and the cryogen load analysis for these events; and

(6.4) a delta-V analysis for the impulse compensation necessary as the result of the propulsive dumping required to sustain propellant settling on an orbital abort, and an assessment of the potential delta-V gain available as the result of either early or late sumping during main engine operation.

9

Table 6-1

CRYOGEN HANDLING

CONDITION	LO_2	LH_2
Normal Mission		
Passivation: (Before Tug capture)	o Keep residual LO_2 o Vent above 18 psia	o Flow residual LH_2 through engine down to 3 psia
Venting: (After Tug capture/ stowage)	o Keep residual LO_2 o Vent above 18 psia	o Vent again to 3 psia o Fill with ambient He to 26.3 psia o Vent down to 16±1 psia o Vent above 18 psia
Aborted Mission		
Suborbital: (Mode III)	Dump LO_2 to 15 psia: (1) During engine firing, 20% minimum through 3" abort line (2) After ET jettison, remainder through 3-inch abort line	Nominal o Keep LH_2 in tank o Vent above 18 psia Alternative Study Options o Dump sequentially after LO_2 (CG constraint) down to 110K ft through 4 or 5 inch abort lines o Dump simult. thru 3-In. line
Orbital: (Mode IV,V,VI)	Dump LO_2 to 15 psia: Primary Method: (1) During orbital flight, 100% through 2-inch F/D port and tap to 3-inch abort line. Alternative (Backup) Method: (1) During orbital flight, ~ 40% through 3-inch abort line (2) During reentry glide, remainder through 3-inch abort line	Preferred-Options 2 & 3F o Dump under vapor pressure to 15 psia o Keep remainder o Vent above 18 psia Preferred-Options 1 & 3I o Dump under vapor pressure to 3 psia o Fill with ambient He to 26.3 psia o Vent down to 16±1 psia o Vent above 18 psia Alternative (Backup) o Keep LH_2 in tank o Vent above 18 psia

Table 6-2

ABORT MODE ANALYSIS SUMMARY AND CONCLUSIONS

Mode I - No dump; continue flight to Modes II or III abort period.

Mode II - No dump; SRB thrust termination eliminated, SRB separation at 115 sec before dumping is permitted (No Mode II abort, as directed by COR instructions).

Mode III - Start LOX dump at T+116 to T+251 sec; 310 to 280 sec are available before MECO-30, 704 to 649 sec after MECO+30.

- o Adequate time is available from a 3-inch LOX dump line for Mode III abort.

6-3

- o Cryogen dump during engine operation is acceptable according to NASA study directives.
- o Dump LOX and/or LH_2 when liquid/gas interface is relatively stabilized.
- o Simultaneous dumping is reported to be acceptable when all the following conditions prevail:
  - LOX and LH_2 outlets are separated by $\geq$ 300 inches
  - Atmospheric pressure $\geq$ 0.1 psia
  - Altitude is $\geq$ 110,000 ft
- o Sufficient time exists above 110,000 ft in a Mode III abort for simultaneous LH_2 dump with a 3-inch line, including dump time before and after MECO.
- o Sufficient time exists above 110,000 ft in a Mode III abort for sequential LH_2 dump with a 4-inch line, including dump time before and after MECO.
- o Insufficient time exists above 110,000 ft in a Mode III abort for LH_2 dump in stable condition, after MECO.
- o Sufficient time exists above 110,000 ft in a Mode III abort for LH_2 dump in variable condition with a 5-inch line, after MECO.
- o Land full will cause an undesirable reduction of payload capability (-2,051 lb)

CONCLUSIONS:

(1) LO_2 dump is recommended for suborbital abort.

(2) LO_2 and LH_2 dump is recommended for orbital abort.

Table 6-3

ABORT STUDY ASSESSMENT

	LAND FULL	DUMP CRYOGENS		
		LO_2 ONLY	LO_2 AND LH_2	
		3 IN. LINE	SEQUENTIAL 3.5 IN. & 5 IN.	SIMULTANEOUS 3 IN. & 5 IN.
Δ TUG WEIGHT (LB)	+806	+144	+177	+164
Δ ORBITER WEIGHT (LB)*	+94	+340	+1303	+1297
Δ PAYLOAD WEIGHT (LB)				
ROUND TRIP**	-815	-178	-307	-294
GEOSYNCH DEPLOY***	-2015	-489	-938	-903

LAUNCH FULL, LAND FULL

- SAFETY ASPECTS QUESTIONABLE
- CANNOT ACCOMMODATE CRASH LOAD FACTORS (ABORT AND CRASH LANDING ARE NOT CONCURRENT CONDITIONS FOR THIS STUDY)
- LANDING CG OUTSIDE OF JSC 07700 PROFILE RANGE

DUMP SYSTEMS

- SUBORBITAL DUMP IN MODE III ABORT (T +116 SEC OR LATER)
- SIMULTANEOUS LH_2 DUMP AND LO_2 DUMP DEPENDS ON TIME AVAILABLE ABOVE 110K FT
- SEQUENTIAL DUMP IS PREFERRED WHEN TIME AVAILABLE, FOR SAFETY MARGIN
- SIMULTANEOUS DUMP SAFETY DEPENDS ON ATMOSPHERE PRESSURE AND OUTLET PORT SEPARATION
- PAYLOAD WEIGHT IMPACT & CG BENEFIT CONTRIBUTE TO LO_2 DUMP PREFERENCE

RECOMMENDATION: LO_2 DUMP

* INCLUDES ANCILLARY EQUIPMENT

** $\Delta W_{PL} = -[\Delta W_{TUG} + 0.1\ (\Delta W_{ORBITER})]$ FOR ROUND TRIP

*** $\Delta W_{PL} = -[\Delta W_{TUG} \times 2.5 + 0.38\ (\Delta W_{ORBITER})]$ FOR DEPLOY TO GEOSYNCH ORBIT

4

6.1 Detailed Timeline of Events

There are several abort conditions to be time-lined. The major abort conditions are suborbital (Mode III) and orbital (Modes IV, V, and VI).

Suborbital Abort

The selected suborbital abort mode is to dump LO_2 and to retain and land with LH_2. Refer to the trade studies in Section 6.12.6 for option time-line descriptions for the other alternative options. The LO_2 is partially dumped (to 20% minimum and approximately 40% maximum) while the orbiter main engines are operating, in order to assure CG compatibility subsequent to External Tank (ET) jettison. The remaining LO_2 is dumped down to 15 psia during the glide return period. The time-line is shown in Table 6.6.1-1.

Orbital Abort

The selected orbital abort technique (for Modes IV, V, or VI) provides settling thrust with the Orbiter OMS engines, then propulsively dump LO_2 down to 15 psia through the 2-inch LO_2 fill and drain line and the bypass valve(s) to the 3-inch LO_2 abort dump line boat-tail exit port. When LO_2 dump is completed, CG compatibility is assured, and the preferred propulsive LH_2 dumping is accomplished through the 2-inch LH_2 fill and drain line and the bypass valve(s) to the 2-inch LH_2 abort dump line boat-tail exit port. A backup operational technique is to dump up to 40% of the LO_2 through the 3-inch side abort dump port, then dump LH_2 as above, and finally to dump the remaining LO_2 after ET jettison and during the glide return. A second backup mode is to use either of the above LO_2 dump modes and to retain the LH_2 to landing.

Essentially the same timelines are used for Modes IV, V, and VI abort. A much longer time is available for dumping than for Mode III suborbital abort. Modes V and VI differ in the amounts of OMS propellants available after boost

Table 6.1-1

Mode III Abort Timeline -- Return to Launch Site, Suborbital

Automatic Orbiter Operations -- Abort Analysis, Initiation, and Sequencing

Perform Situation Analysis

Make Preliminary Abort Decisions

Report Status to Ground

Obtain Concurrence with Flight Data Base for Abort

Obtain Abort Confirmation

Display Condition/Status/Abort Command to Crew -- Crew will have a brief period for the abort command notification, except in the time-critical transition from Mode III to Mode IV abort at T+121 to T+126. Reaction time must be very fast to obtain Mode III return to launch site when a Mode IV OAO is not yet achievable. Command over-ride for abort is not feasible at this time, but a recheck may be commanded when response time is sufficient.

Automatic Orbiter Operations -- Abort

Reprogram Flight Control/GNC to Abort Mode III

Insert Abort ΔV Adjustment in Engine Thrust Program

Switch Engines to EPL (109%), Assuming Engine Failure Precipitated Abort

Ignite Two OMS Engines and Four RCS X-Axis Thrusters (Orbiter)

Pitch Orbiter to Retro-Thrust Attitude

Verify Emergency Thrust/Velocity/Attitude per Abort Mode III Program

Change Orbiter Velocity from Down-Range to Up-Range

Verify Dump/Vent Valve Positions/Status

Activate Abort Dump System

Open LO_2 Abort Dump Valve (3-inch line)

Open Helium Pressurization Valve

9

Table 6.1-1 (Cont)

Verify LO_2 Dumping (Δ^2V or ΔV readout, visual, etc.)

Verify 20% Minimum to 40% Maximum LO_2 Dump Completion

Reclose and Verify Helium Pressurization Valve Closure

Reclose and Verify LO_2 Dump Valve Closure

Separate External Tank (ET) After Depletion

Establish Attitude and G-Profile for Dumping

Fly an Orbiter Return Flight Profile as Appropriate for Abort Mode III

Open LO_2 Abort Dump Valve (3-inch line)

Open Helium Pressurization Valve

Verify LO_2 Dumping

Monitor LO_2 Tank Pressure

At 15 psia LO_2 Tank Pressure, Reclose and Verify Helium Pressurization Valve Closure

Reclose and Verify LO_2 Abort Dump Valve

Monitor LO_2 Tank Pressure and Vent Above 18 psia down to 16 $\pm$ 1 psia

Monitor LH_2 Tank Pressure and Vent Above 18 psia down to 16 $\pm$ 1 psia

Note: Interlock Vent Control to Avoid Simultaneous Venting to different altitudes and inclunations. These do not appreciably affect the abort operations. There are about 105 minutes in a Mode IV Once-Around-Orbit (OAO) abort, of which at least 90 minutes are available for dumping cryogens. The later Modes V and VI have many orbits and are not time constraining, as they allow essentially normal mission Orbiter operations. Release of the Tug may be possible. The timeline for these abort modes is shown in Table 6.1-2.

Table 6.1-2

Modes IV, V, and VI Abort Timeline — Orbital

Automatic Orbiter Operations -- Abort Analysis, Initiation and Sequencing

Monitor Orbiter and Tug Mission - Critical Functions and Flight Data During Launch

Perform Situation Analysis

Make Preliminary Abort Decisions

Report Status to Ground

Obtain Concurrence with Flight Data Base for Abort

Obtain Abort Confirmation

Display Condition/Status/Abort Command to Crew (*Note 1)

Automatic Orbiter Operations -- Abort

Reprogram Flight Control/GNC to Abort Modes IV, V, or VI (normal mission for V, VI)

Insert Abort ΔV Adjustment in Engine Thrust Program

Switch Engines to EPL (100%), Assuming Engine Failure Precipitated Abort

Ignite Two OMS Engines and Four RCS X-Axis Thrusters (Orbiter) for Mode IV (not required for Modes V and VI)

Verify Emergency Thrust/Velocity/Attitude per Abort Modes IV, V, or VI Program

Verify Dump/Vent Valve Positions/Status

Verify OMS Engine Thrust for Cryogen Settling

Activate Abort Dump System

Open LO_2 Abort Dump Valves (2-inch fill and drain and 3-inch aft abort lines)

Open Helium Pressurization Valve

Verify LO_2 Dumping (Δ^2V or ΔV readout, visual, etc.)

Monitor LO_2 Tank Pressure

At 15 psia LO_2 Tank Pressure, Reclose and Verify Helium Pressurization Valve

Reclose and Verify LO_2 Abort Dump Valve

During this Sequence, Interrupt Dumping 30 Seconds Before ET Jettison and Resume Dumping 30 Seconds After ET Jettison

Monitor LO_2 Tank Pressure and Vent Above 18 psia Down to 16 ± 1 psia

Open LH_2 Valves to Fill and Drain and 2-inch Aft Abort Lines

<u>The Following Operations Apply to Tug Options 1 and 3I Only:</u>

Dump LH_2 Under Vapor Pressure to 3 psia

Reclose LH_2 Valves and Verify Closure

Open Helium Pressurization Valve

Monitor LH_2 Tank Pressure and Fill with Helium to 26.3 psia (or to Tank Relief Vent Pressure)

Reclose Helium Pressurization Valve and Verify Closure

Open LH_2 Valves to Fill and Drain and 2-inch Aft Abort Lines

<u>The Following Operations Apply to All Tug Design Options:</u>

Dump LH_2 Under Vapor Pressure to 16 ± 1 psia

Reclose LH_2 Valves and Verify Closure

Monitor LH_2 Tank Pressure and Vent Above 18 psia Down to 16 ± 1 psia

*Note 1: Crew will have a brief period for the abort command notification, except in the time-critical transition from Mode III to Mode IV abort at T+121 to T+126. Reaction time must be very fast to obtain Mode III return to launch site when a Mode IV OAO is not yet achievable. Command over-ride for abort is not feasible at this time, but a recheck may be commanded when response time is sufficient.

Table 6.1-2 (Cont)

Note 2: Interlock vent controls to avoid simultaneous dumping.

Note 3: An alternative LO_2 dump mode is to dump up to 40% through the 3-inch LO_2 abort line (bottom port) rather than the aft 2-inch fill and drain line tap to the 3-inch aft abort line port. In this event, the remaining LO_2 dump to 15 psia is accomplished after reentry during glide return.

Note 4: An alternative LH_2 dump mode is to keep all LH_2 in tank and only vent above 18 psia.

6.2 Shuttle Requirements

The Shuttle requirements placed upon the Tug operation are principally described by NASA Document JSC-07700, Volume XIV, Space Shuttle System Payload Accommodations. For example, the CG profiles shown in Figures 6.6.2-1 and 6.6.2-2 represent major constraints upon the Tug design and operations. These apply when the ET is jettisoned and the Orbiter is in sensible atmosphere, generally considered below 400,000 ft, in the aerodynamic flight regime. Specifically, these apply in hypersonic and subsonic, but not in supersonic flight. Safety dictates that CG compatibility be achieved before the unstable flight regime is approached, however. Furthermore, a condition where failure to dump cryogens would result in unsafe flight should be avoided. Two methods are provided for dumping a minimum of 20% of LO_2, which is sufficient to assure CG compatibility for recntry and landing.

The Shuttle also requires discrete valve status signals and time-clock inputs to compute the cryogen inventory during dumping. In particular, the ≈40% orbital LO_2 dump in the Alternative (Backup) Method must be computed for valve reclosure to prevent unporting and a sudden drop of pressure, which if not recovered could cause a risk of LO_2 tank implosion at low altitude. In the selected Primary Method, the aft 2-inch LO_2 fill and drain line port is used, and unporting cannot occur during propulsive dumping. The latter method is also used for orbital LH_2 dumping, through the fill and drain line port and unporting is not a potential problem. Suborbital dumping has a requirement for computing LO_2 inventory for partial dumping of 20% to 40%, but this wide range allows the data and the computations to be very gross.

New Shuttle Requirements

The selected abort dumping system requires a fixed 3-inch LO_2 abort dump line from the lower right aft cargo bay bulkhead to the lower right Orbiter boat-tail,

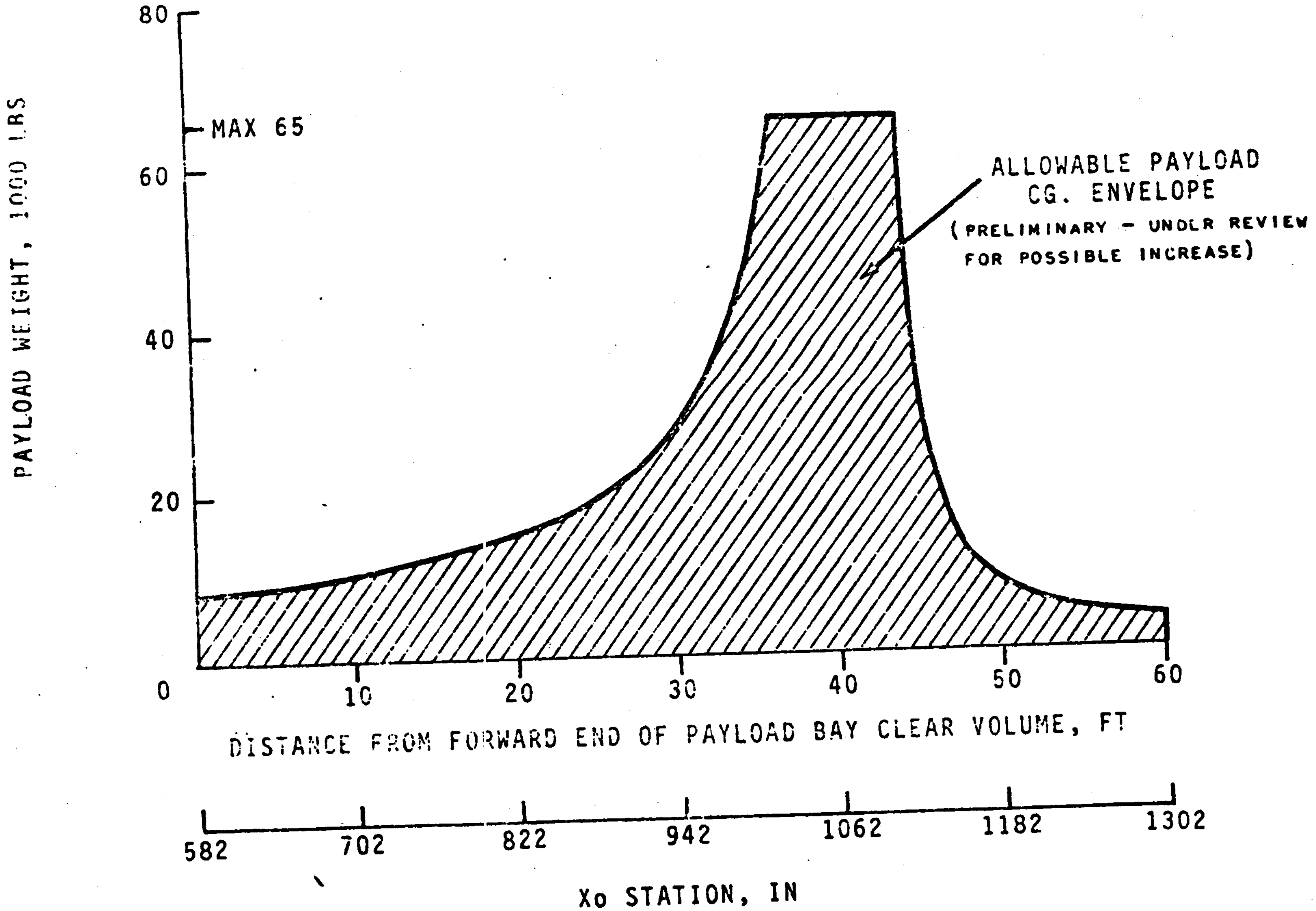


Figure 6.2-1. Payload Longitudinal CG Envelope (Design Specification)

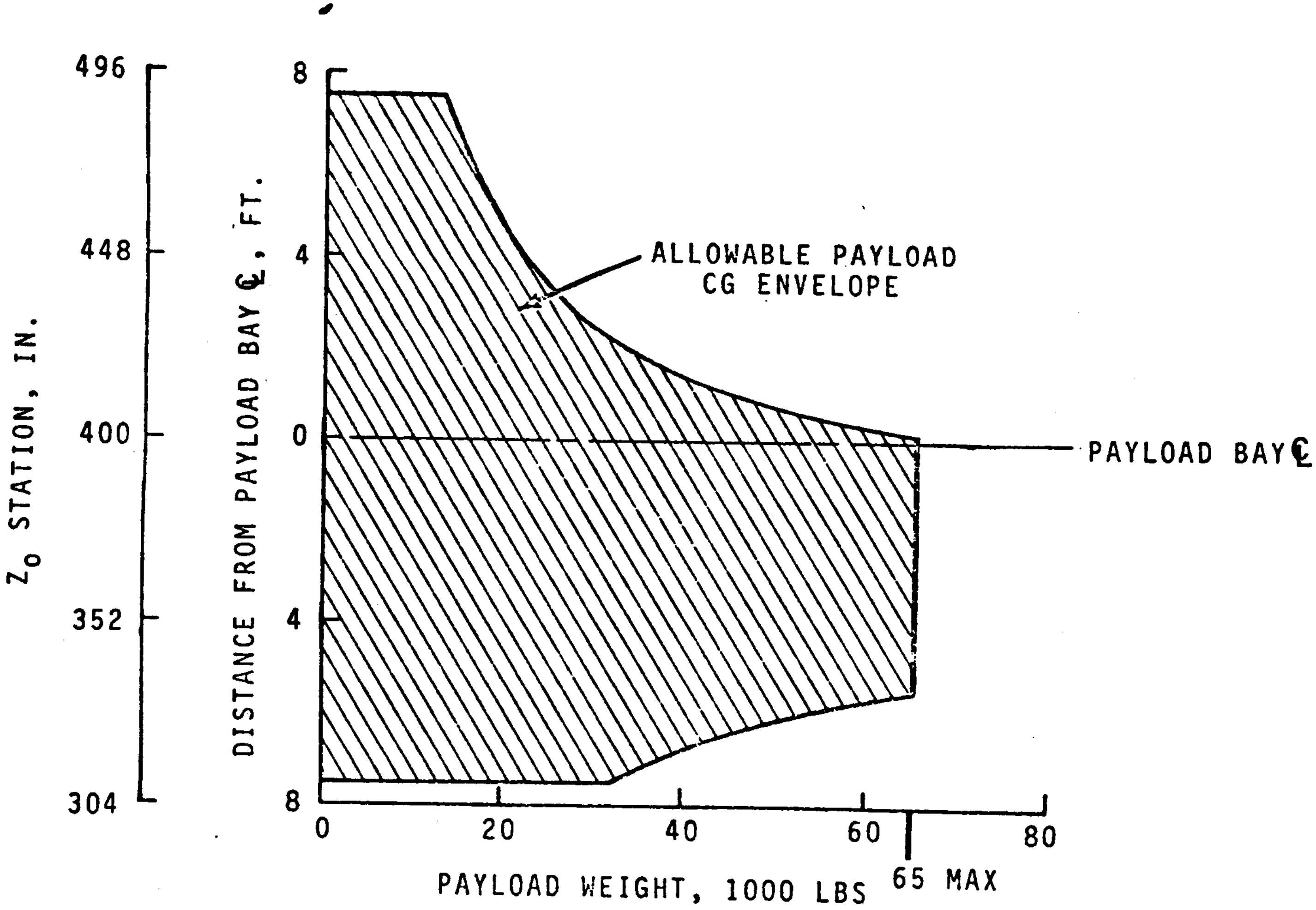


Figure 6.2-2. Payload Vertical CG Envelope

and a similar 2-inch LH_2 abort dump line (for orbital abort) from the lower left aft cargo bay bulkhead to the lower left Orbiter boat-tail.

6.3 Altitude and Time Analysis

The altitude of the Orbiter is shown in Figures 6.3-1, 6.3-2, 6.3-3, and 6.3-4 for suborbital Mode III aborts as a function of velocity. Insufficient data was provided to obtain an altitude versus time profile for these trajectories, which were revised extensively during the study. Information on normal trajectories was referenced by NASA documentation as IL-SSS-393-400-73-045, "Baseline Ascent Trajectories for the 150K Orbiter Configuration," dated February 14, 1973, but this information was also withheld from this study. Earlier information indicated that at least 105 minutes are available on a Mode IV abort to a once-around orbit. This is the shortest orbital abort, and the time available is far greater than the time required for 100% dumping of both LO_2 and LH_2. Mode V is a transitional abort and is virtually identical, time-wise, to a Mode VI normal mission orbital abort. Thus the missing information is not considered relevant to constrain the time-lines.

Summaries of abort modes, associated flight periods and the abort response actions permissible are shown in Table 6.3-1.

The time available for the most recent abort profile data (July 5, 1973), the altitudes, the associated mission times, the x-axis accelerations (N_x) and the z-axis accelerations (N_z) are listed in Tables 6.3-2 and 6.3-3. The time periods during which stable and variable (stable-plus-varying) accelerations are sustained for cryogen settling are also shown.

An abort time summary is presented in Table 6.3-4 for either LO_2 or LH_2, for the early or late abort from either a 40,000 lb polar or a 65,000 lb easterly mission.

LW ORBITER ASCENT ABORT MODE III — ALTITUDE-VELOCITY PROFILE

- POLAR MISSION
- INPLANE MANEUVER
- T_{ABORT} = 116.334 SEC
- LOSS OF ONE MAIN ENGINE
- 2 MAIN ENGINES AT 109% EPL
- NO WINDS

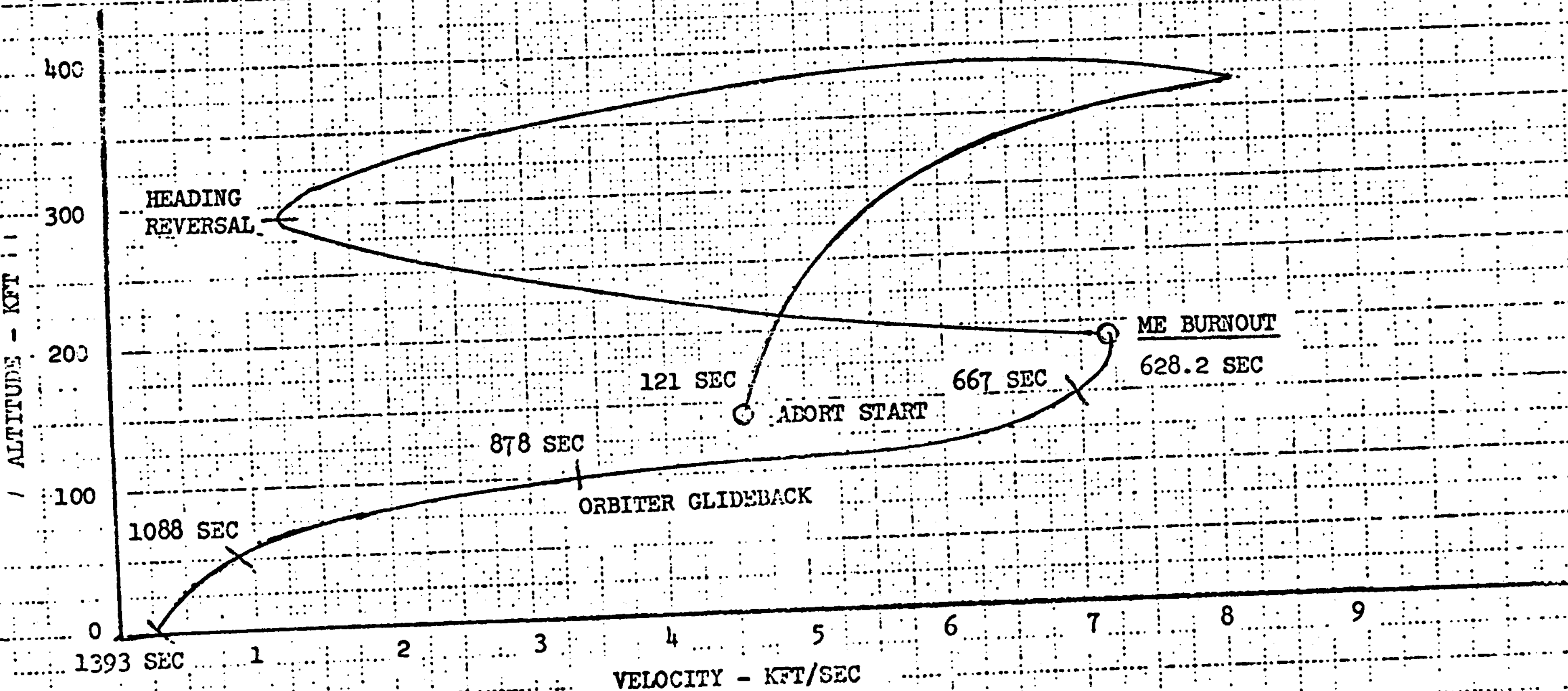


Figure 6.3-1

LW ORBITER ASCENT ABORT MODE III — ALTITUDE-VELOCITY PROFILE

- o POLAR MISSION
- o INPLANE MANEUVER
- o T_{ABORT} = 256 SEC
- o LOSS OF ONE MAIN ENGINE
- o 2 MAIN ENGINES AT 109% EPL
- o NO WINDS

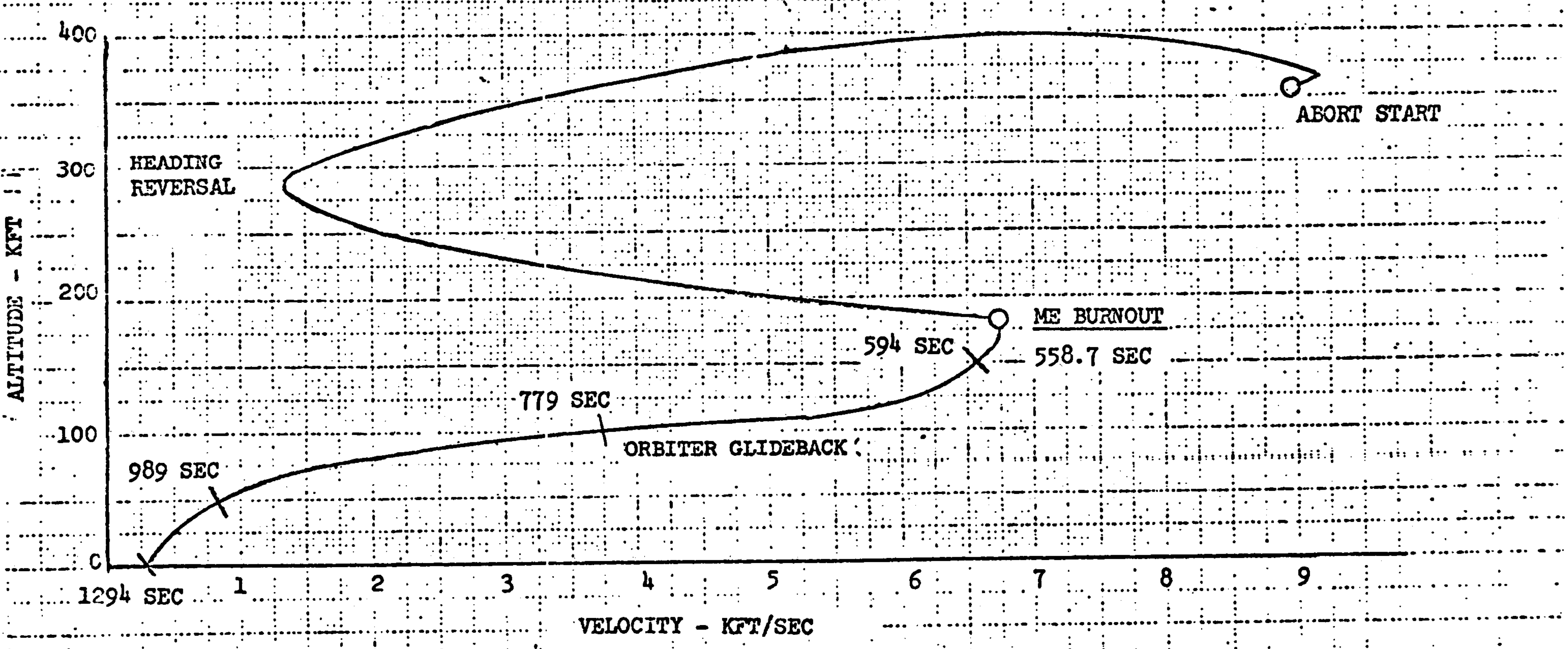


Figure 6.3-2

LW ORBITER ASCENT ABORT MODE III -- ALTITUDE-VELOCITY PROFILE

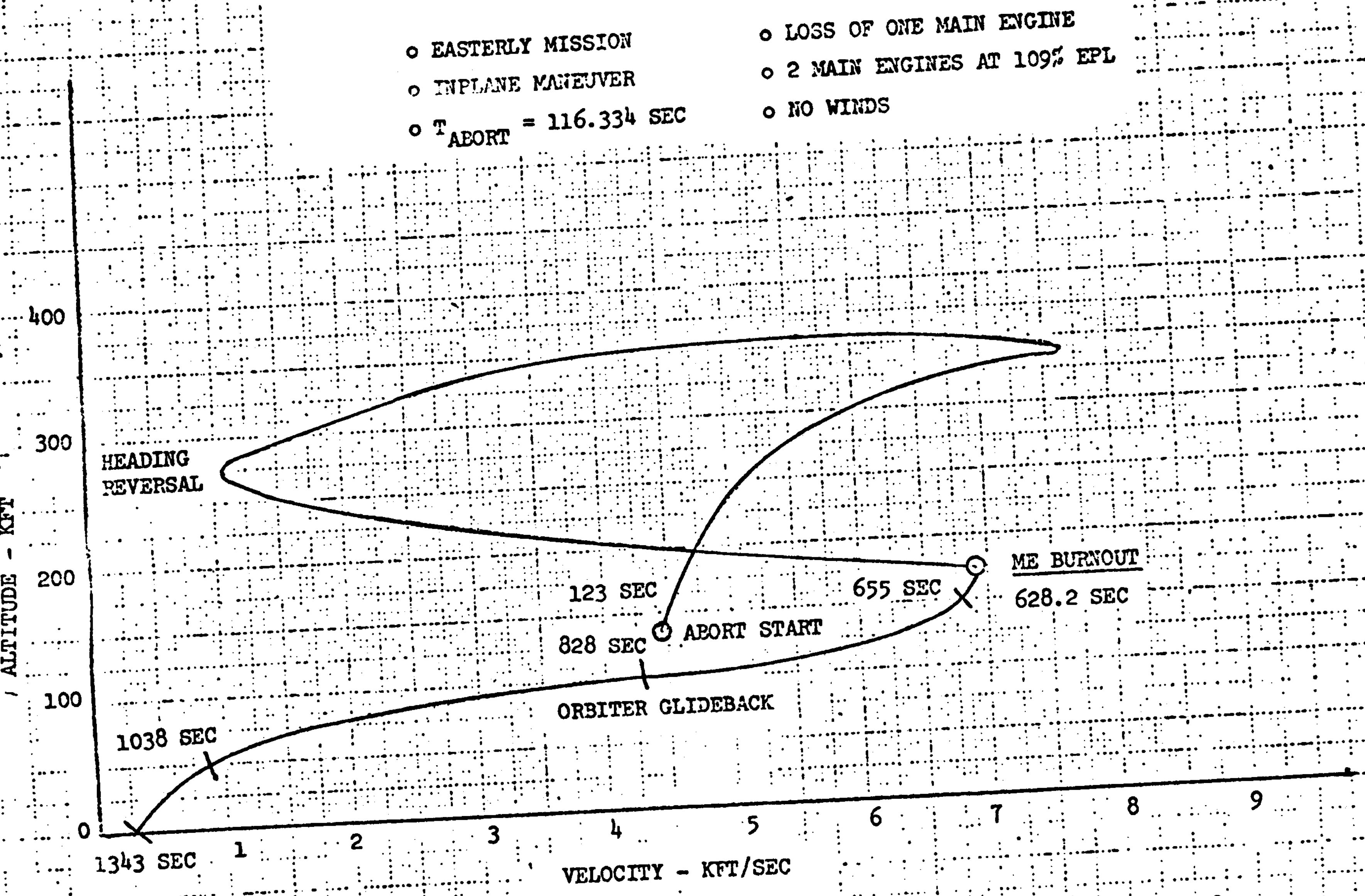
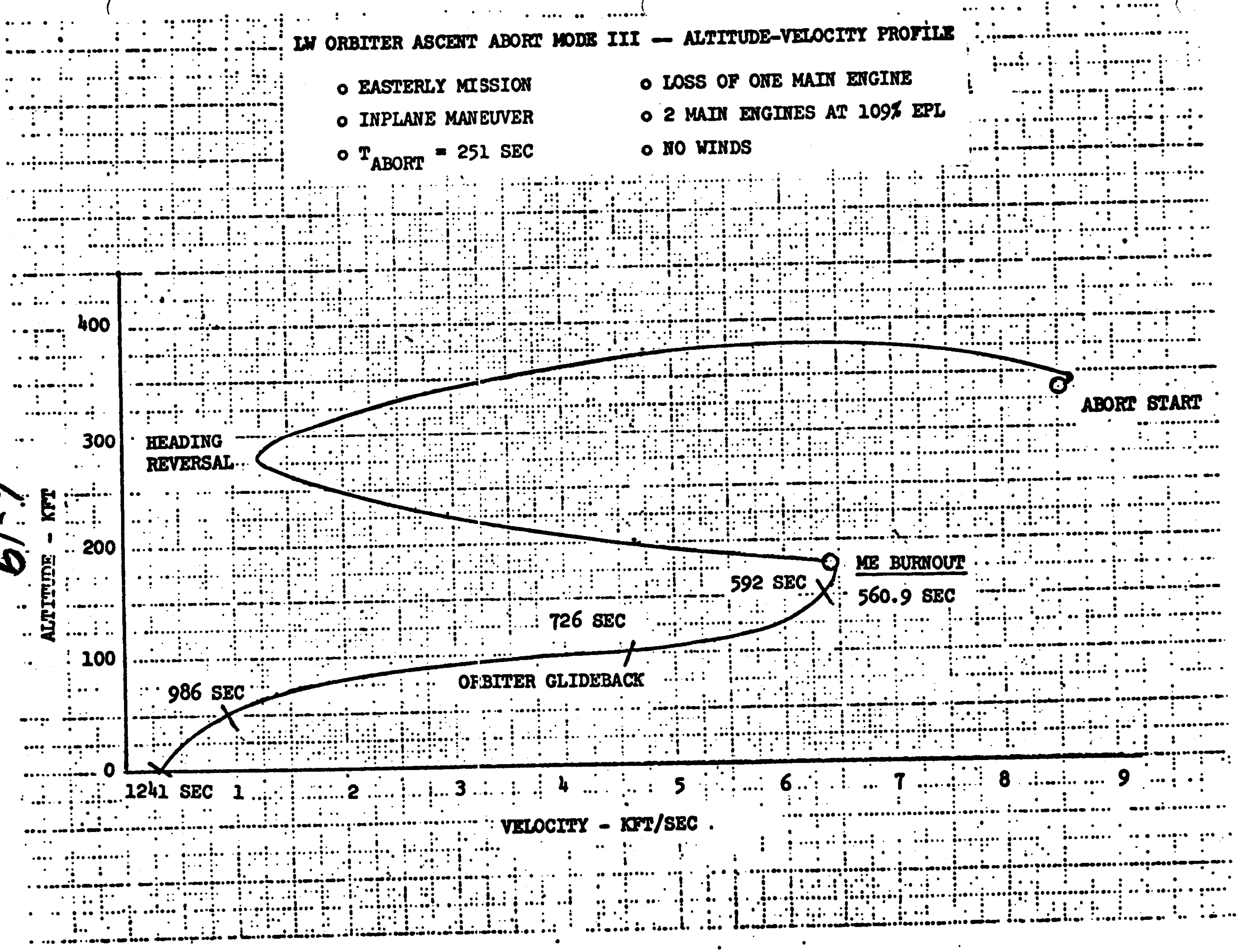


Figure 6.3-3

8/-9



LW ORBITER ASCENT ABORT MODE III — ALTITUDE-VELOCITY PROFILE
o EASTERLY MISSION
o INPLANE MANEUVER
o T_{ABORT} = 251 SEC
o LOSS OF ONE MAIN ENGINE
o 2 MAIN ENGINES AT 109% EPL
o NO WINDS
ABORT START
HEADING REVERSAL
ME BURNOUT
560.9 SEC
592 SEC
726 SEC
ORBITER GLIDEBACK
986 SEC
1241 SEC
ALTITUDE - KFT
400
300
200
100
0
1
2
3
4
5
6
7
8
9
VELOCITY - KFT/SEC

Figure 6.3-4

Table 6.3-1

ABORT DUMP ANALYSIS
ABORT MODES

REFERENCE: NASA-JSC-ME-12-833 (ABORT TRAJECTORIES FOR MISSION 3A, PRELIMINARY), MODIFIED BY COR DIRECTION IN MSFC-PD-TUG-6-73-146 FOR MODE III ABORT.

ABORT MODE	FLIGHT TIME (SEC)	ABORT RESPONSE ACTION
I	0-36	RETAIN LOX, CONTINUE TO MODE II OR III; OR OCEAN DITCH INTACT AFTER T+20 SEC
II (GLIDE)	36-86	ABORT NOT PERMITTED UNTIL SRB SEPARATION AT T+116; CONTINUE TO MODE III ABORT AT T+116
III (RTLS)	80-253 T+116 EASTERLY	512 SEC POWERED PLUS 715 SEC GLIDE AVAIL FROM T+116 (INCLUDING 95 SEC ERRATIC AND 593 SEC STEADY PROPELLANT SETTLING PERIODS)
	T+251 EASTERLY	310 SEC POWERED PLUS 680 SEC GLIDE AVAIL FROM T+251 (INCLUDING 134 SEC ERRATIC AND 515 SEC STEADY PROPELLANT SETTLING PERIODS)
IV (AOA)	253-330	105 MINUTES AVAILABLE
V (ATO)	N/A	
VI (NORMAL MISSION)	330 TO INSERTION	220 SECONDS REQUIRED FROM T+330 TO INSERTION

RTLS = RETURN TO LAUNCH SITE

AOA = ABORT ONCE AROUND

ATO = ABORT TO ORBIT

Table 6.3-2

NEW ABORT PROFILE DATA - I

5 JULY 1973

EARLY MODE III ABORT

SRB THRUST TERMINATION AT T + 116.334 SEC

ABORT INITIATED AT T + 121 SEC

OMS BURNOUT:

T + 249.314 FOR 40K LB POLAR FLIGHT

T + 512.534 FOR 65K LB DUE EAST FLIGHT

MAIN ENGINE BURNOUT:

T + 628.205 FOR BOTH FLIGHT PROFILES

ALTITUDE	POLAR ORBIT			DUE EAST ORBIT		
	TIME	N_x	N_z	TIME	N_x	N_z
190K FT	628.2*	+3.5→0	+0.5→0	628.2*	3.15→0	+0.55→0
150	667	-0.1	-1.45	655	-0.05	-0.85
100	878	-0.2	-1.0	828	-0.2	-1.0
50	1088	-0.15	-1.0	1038	-0.25	-1.1
LAND	1393	0	-1.0→0	1343	0	-1.0→0

* MECO - MAIN ENGINE CUT OFF

STABLE REGIONS:

POLAR MISSION: T + 770 TO 1393 LANDING
110 SEC TO 110 K FT

DUE EAST MISSION: T + 750 TO 1343 LANDING
≤ 78 SEC TO 110K FT

VARIABLE REGIONS:

POLAR MISSION: T + 667 TO 1393
203 SEC TO 110 K FT

DUE EAST MISSION: T + 655 TO 1343
173 SEC TO 110K FT

Table 6.3-3

NEW ABORT PROFILE DATA - II

5 JULY 1973

LATE MODE III ABORT

SRB THRUST TERMINATION AT T + 116.33.4 SEC

ABORT INITIATED AT T + 256 SEC (40K LB POLAR, AT T + 251 SEC (65K LB DUE EAST)

OMS BURNOUT:

T + 388.98 FOR 40K LB POLAR

T + 560.863 FOR 65K LB DUE EAST

MAIN ENGINE BURNOUT:

T + 558.7 FOR 40K LB POLAR

T + 628.2 FOR 65K LB DUE EAST

ALTITUDE	POLAR ORBIT			DUE EAST ORBIT		
	TIME	N_x	N_z	TIME	N_x	N_z
175K FT	558.7*	+3.5-0	+0.6-0			
180K FT				560.9*	+3.2-0	+0.4-0
150K FT	594	-0.1	-0.95	592	-0.05	-1.25
100K FT	779	-0.2	-1.0	726	-0.2	-1.1
50K FT	989	-0.15	-1.05	936	-0.15	-1.05
LAND	1294	0	-1.0	1241	0	-1.0

* MECO - MAIN ENGINE CUT OFF

STABLE REGIONS: POLAR MISSION: T + 700 TO 1294 LANDING
75 SEC TO 110K FT

DUE EAST MISSION: T + 726 TO 1241
0 SEC TO 110K FT

VARIABLE REGIONS: POLAR MISSION: T + 594 TO 1294
181 SEC TO 110 FT

DUE EAST: T + 592 TO 1241
134 SEC TO 110K FT

Table 6.3-4

ABORT TIME SUMMARY
TIME AVAILABLE FOR DUMPING CRYOGENS

	LOX		LH_2	
	STABLE (SEC)	VARIABLE (SEC)	STABLE (SEC)	VARIABLE (SEC)
o EARLY ABORT (T+121)				
40KLB POLAR MISSION	623	726	100	203
65KLB DUE-EAST MISSION	593	688	78	173
o LATE ABORT (T+256, 251)				
40KLB POLAR MISSION	594	700	75	181
65KLB DUE-EAST MISSION	515	649	0	134

"VARIABLE" INCLUDES ALL TIME IN WHICH PROPELLANTS ARE UNDER G-FORCES TO COVER THE DUMP OUTLET, WITH BOTH STABLE AND VARYING ACCELERATION VALUES.

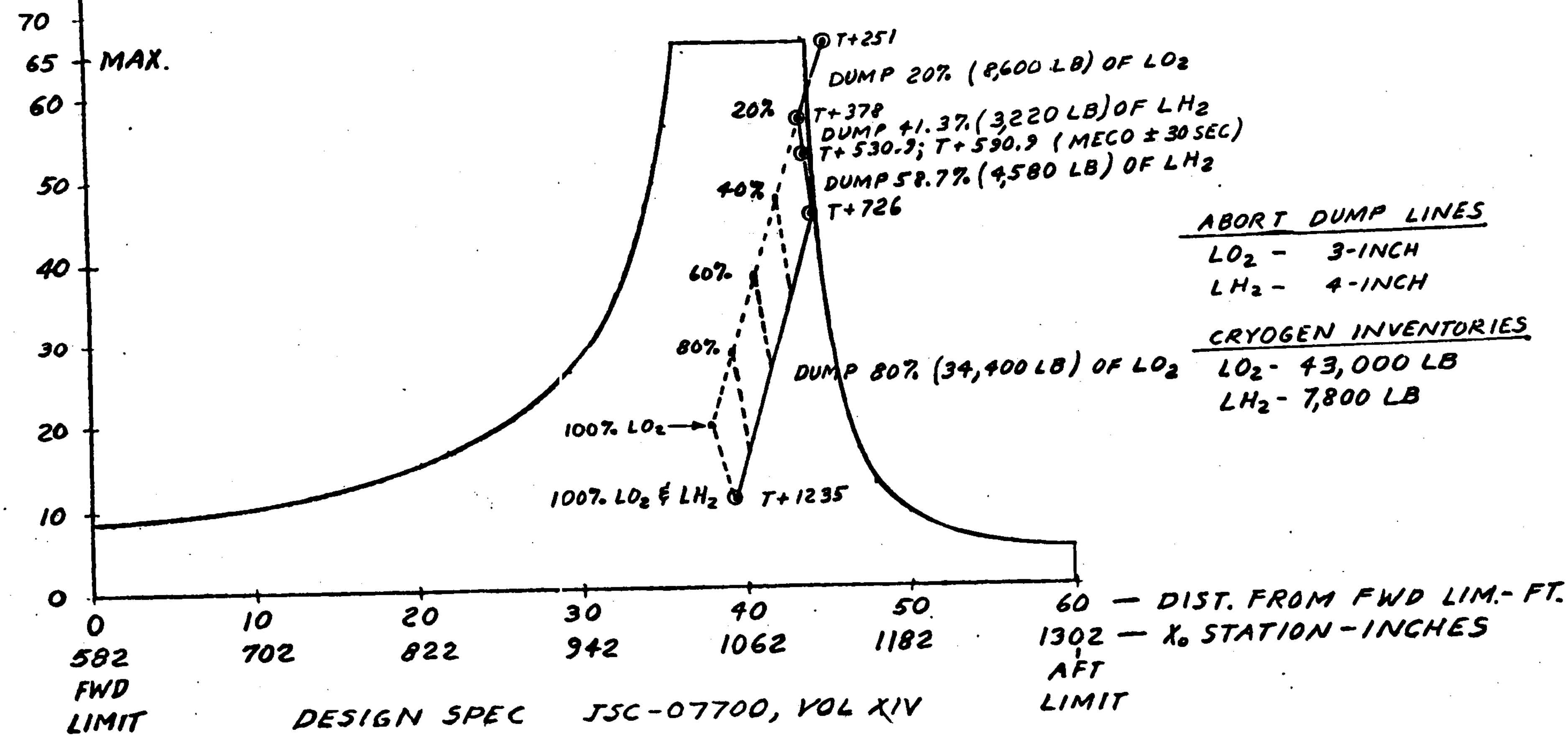
A plot of the cryogen load and center of gravity (C.G.) shift during dumping is shown on Figure 6.3-5. This was originally derived to illustrate the cases of sequential dumping. However, the complexity of alternating the LO_2 and LH_2 dumping sequence and the weight penalty on payload capability led to the recommendation that only LO_2 be dumped during a suborbital abort.

Combining the trajectory vs. time data from Figure 6.3-4 and the C.G. constraints from Figure 6.3-5, a safe timeline was devised to provide the Orbiter ΔV benefit of early dumping, the C.G. constraints to assure aerodynamic stability and landing control as early as possible, and a 100% release of LO_2 will before landing. This recommended abort mode is shown on Figure 6.3-6. The LO_2 dumping is interrupted for 60 seconds as indicated to allow for main engine cutoff (MECO) and external tank (ET) jettison and a 30 second margin before and after this event, known as MECO ± 30.

The LO_2 dumping sequence is shown on the trajectory curve in Figure 6.3-7. The same time periods are required for dumping LO_2 (635 seconds total) for the trajectories shown in Figure 6.6.3-1, -2, and -3. However, in each case, more time is available from the abort decision to MECO - 30. Therefore, as it is recommended to initiate dumping as early as possible; these trajectories will allow a greater degree of completion prior to MECO - 30.

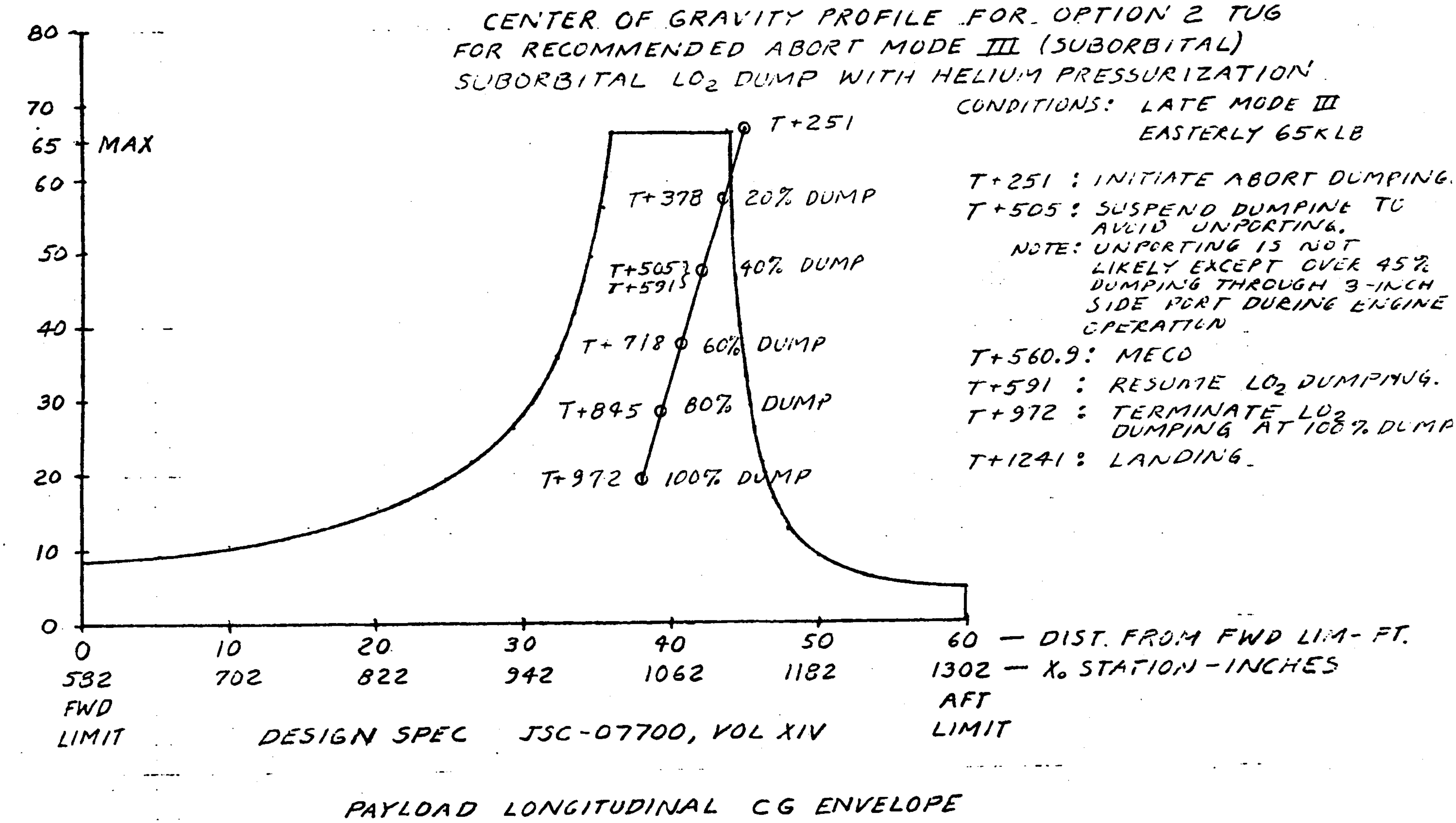
This analysis is based on the worst-case data for Tug Design Option 2, which requires 635 seconds for 100% LO_2 dump. The differences in LO_2 inventory result in equivalent times for LO_2 dump of 505 seconds for Tug Option 1 and 3I (Initial) and 530 seconds for Tug Option 3F (Final). In each case the dump is suspended at 40% dump level, which occurs at proportionally earlier times. The event schedules are shown in Table 6.3-5 for comparison.

OPTIMIZED SEQUENTIAL ABORT DUMPING
LATE ABORT AT T+251, MODE III



PAYLOAD LONGITUDINAL CG ENVELOPE

Figure 6.3-5



CENTER OF GRAVITY PROFILE FOR OPTION 2 TUG
FOR RECOMMENDED ABORT MODE III (SUBORBITAL)
SUBORBITAL LO2 DUMP WITH HELIUM PRESSURIZATION
CONDITIONS: LATE MODE III
EASTERLY 65KLB
T+251 : INITIATE ABORT DUMPING.
T+505 : SUSPEND DUMPING TO AVOID UNPORTING.
NOTE: UNPORTING IS NOT LIKELY EXCEPT OVER 45% DUMPING THROUGH 3-INCH SIDE PORT DURING ENGINE OPERATION.
T+560.9: MECO
T+591 : RESUME LO2 DUMPING.
T+972 : TERMINATE LO2 DUMPING AT 100% DUMP
T+1241: LANDING.
PAYLOAD WEIGHT- KLB
80
70
65
MAX
60
50
40
30
20
10
0
T+251
T+378
20% DUMP
T+505
T+591
40% DUMP
T+718
60% DUMP
T+845
80% DUMP
T+972
100% DUMP
0
10
20
30
40
50
60 — DIST. FROM FWD LIM- FT.
532
702
822
942
1062
1182
1302 — X0 STATION-INCHES
FWD LIMIT
AFT LIMIT
DESIGN SPEC JSC-07700, VOL XIV
PAYLOAD LONGITUDINAL CG ENVELOPE

Figure 6.3-6

LW ORBITER ASCENT ABORT MODE III — ALTITUDE-VELOCITY PROFILE

- o EASTERLY MISSION
- o INPLANE MANEUVER
- o T_{ABORT} = 251 SEC
- o LOSS OF ONE MAIN ENGINE
- o 2 MAIN ENGINES AT 109% EPL
- o NO WINDS

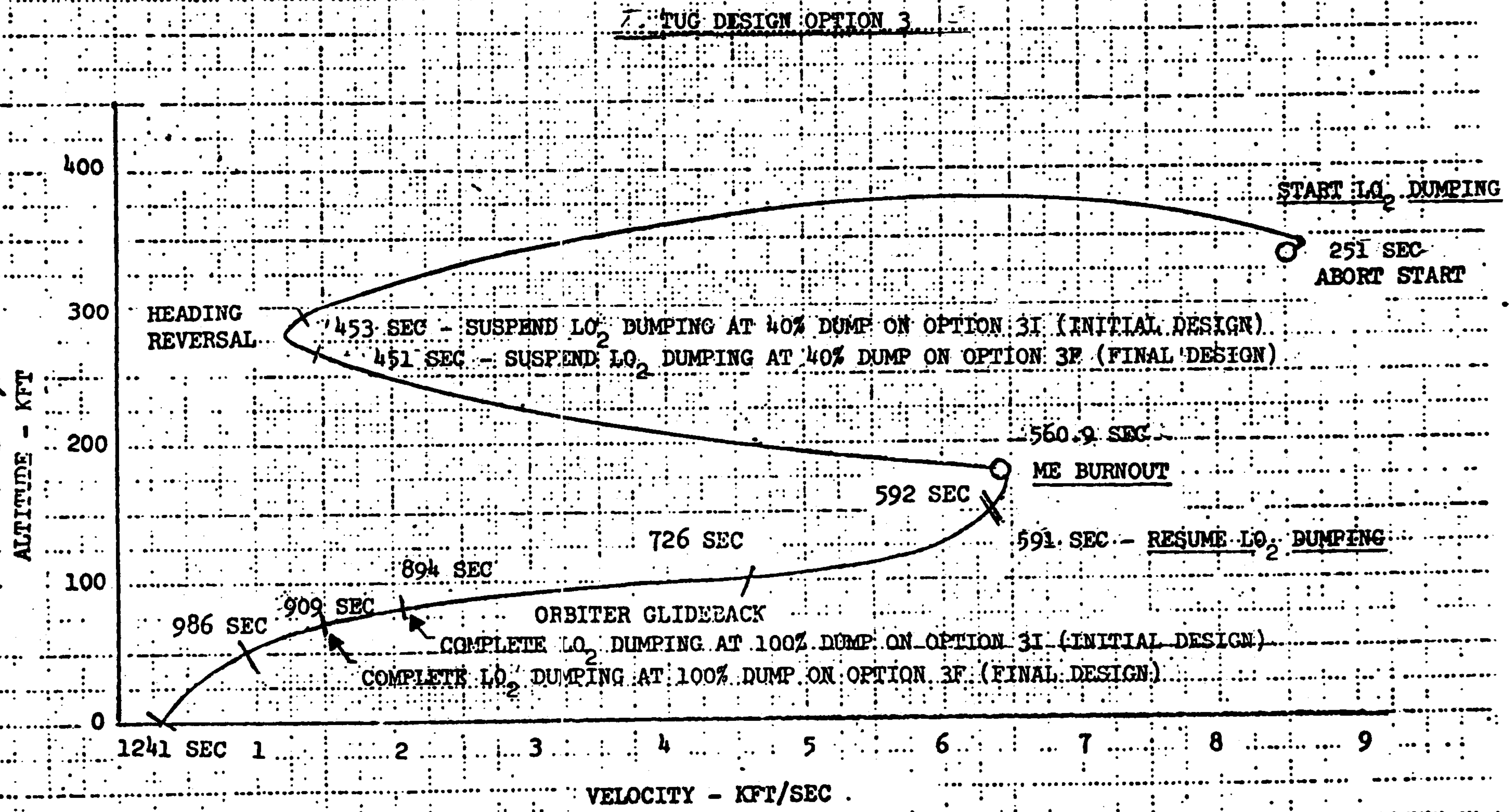


Figure 6.3-7

9

Table 6.3-5

ABORT EVENT SCHEDULES

TUG OPTION	1	2	3I	3F
LO_2 ABORT LINE SIZE	3 inch	3 inch	3 inch	3 inch
TIME FOR 100% LO_2 DUMP	505 sec	635 sec	505 sec	530 sec
DUMP INITIATION (WORST CASE)	T+251	T+251	T+251	T+251
DUMP SUSPENSION	T+453	T+505	T+453	T+463
MECO	T+560.9	T+560.9	T+560.9	T+560.9
DUMP RESUMPTION	T+591	T+591	T+591	T+591
DUMP COMPLETION	T+894	T+972	T+894	T+909
TIME AT 50,000 FT	T+986	T+986	T+986	T+986
TIME AT LANDING	T+1241	T+1241	T+1241	T+1241

6.4 Delta V Analysis

Two aspects of abort delta V were examined. The first is concerned with the delta V produced by the propulsive dumping which is necessary to sustain propellant settling in an orbital zero-g abort. The second is concerned with the potential delta V gain which is achievable by the Orbiter by early Mode III abort dumping after as much of the Orbiter wieght has been depleted as possible; hence, after External Tank (ET) propellants are exhausted and the ET has been jettisoned to achieve the highest delta-V gain

Delta V Compensation in Orbital Abort of LO_2 and LH_2

Addressing the first aspect, delta V compensation in an orbital abort, the potential solutions all require that the propulsive effect expressed by Orbiter delta-V be negated. Potential solutions are (1) reduced thrust from the OMS, RCS x-axis thrusters, or the main engines, (2) reduced thrusting time by the OMS, RCS x-axis thrusters, or the main engines, (3) rotation of the Orbiter during cryogen dumping to retro-thrust for a time equal to the forward thrust time, using the cryogen expulsion force, (4) yaw to +90° and to -90° to provide equal and opposite thrusting forces and times, (5) dump Tug cryogens before the OMS or the main propulsion system (MPS) burns, (6) dump Tug cryogens during OMS and/or MPS burn, (7) interrupt OMS and/or MPS burns to save sufficient propellant and adjust the delta V with a shorter final burn duration, or (8) use a computed abort delta V to bias (shorten) the OMS and/or MPS burns and thus to compensate for abort delta V. It should be noted that these solutions use either (1) a "thrust-spoiling" or counter-reactive negation technique, or (2) a "compensation" technique in connection with major propulsion systems and in these cases, excess cryogen is jettisoned with the ET in the cases of reduced MPS burns or is dumped before reentry in the cases of OMS burns. It should be emphasized that the OMS burn adjustment therefore only transfers the problem from Tug to Orbiter, and thus represents no real solution.

The propulsive abort dumping delta V problem applies only to orbital abort primarily due to the more precise reentry velocity and time constraints from orbit. The plan to dump during main engine burn will minimize the problem for a suborbital abort, and adjustment of velocity is more readily accomplished to compensate for cryogen dumping.

The dumping delta V problem, discussions, and conclusions are characterized for a once-around-oribt (OAO) Mode IV abort as representatige of all orbital abort modes.

Delta V Compensation for Once-Around-Orbit (OAO) Abort Dumping

This discussion represents an operational solution to a problem raised by an action item question and a NASA response, quoted below. The NASA response reflects one solution to the potential problem. However, it is very constraining to limit abort dumping to the Orbiter thrust period alone, and other options have been examined.

Reference: NASA-MSFC Memorandum PD-DO-DIR-73-57, dated June 7, 1973, extract:

"Action Item 2: Can Tug propellants be dumped in the X axis of the Orbiter to provide propellant settling during the once around abort (OAO) mode?

Response: In discussions with JSC we were told that the OAO abort trajectory after Orbiter thrust termination is critical and may not be able to correct for any ΔV resulting from propellant settling thrust and Tug propellant dumping. JSC therefore requested that any Tug propellant dumping during an OAO abort should be completed before Orbiter thrust termination so that the ΔV imparted by the propellant dumping can be corrected."

Alternatives

1. Reduced thrusting forces from OMS, MPS, or RCS (x-axis).
2. Reduced thrusting time for OMS, MPS, or RCS (x-axis).
3. Rotation to 180° and retro-thrust.
4. Rotation to +90° and -90° and counter-thrust.
5. Dump before OMS, MPS, or RCS burns.
6. Dump during OMS, MPS, or RCS burns.
7. Interrupt OMS, MPS, or RCS burns and adjust ΔV with final burn duration.
8. Use a computed abort ΔV to bias the OMS, MPS, or RCS burn and thus compensate for abort dump ΔV.

Analysis

1. Thrust management of OMS or MPS during the late burn period is more effective than early adjustment, due to the lower total weight. A more accurate result is obtained by adjusting the total thrust (abort dump thrust plus primary propulsive thrust) to match the programmed flight requirements. The best alternative is to reduce MPS or RCS rather than OMS thrust level, so the unused propellant is either jettisoned (MPS) or returned (RCS), assuming either OMS burn or propulsive dumping is baselined for an aborted mission.

2. Thrust-time management of OMS, MPS, or RCS is similar to alternative No. 1, and is effective to the same degree. The programmed total thrust technique, however, must be changed to a programmed total impulse technique using accelerometers and a clock to determine delta V and to match the programmed orbital abort flight profile. Again, it is best to use MPS or RCS as the adjustable propulsion energy source, depleting OMS propellants completely.
3. Retro-thrust management represents some control complexity and relies on computed delta V, using acceleration and time as inputs, as the control variable. This is an effective method if it is operationally acceptable to the Orbiter.
4. Left and right yaw thrust management is the same as alternative No. 3 in most respects. It can be used to effect any desired cross-range adjustment, as well.
5. Dump before MPS burn is not practical, since MPS burns from launch. OMS burn is started later, and could be delayed. However, the dumping time for LO_2 and LH_2 would usually exceed the OMS ignition delay time and the dump would be at least partially concurrent with OMS burning.
6. Dump during MPS and OMS burn is possible; however, a Mode IV abort is initiated from T+253 to T+330 seconds, a Mode V from T+330 to T+490 seconds, and a Mode VI (normal mission orbit) after 550 seconds. Considering the delta V problem for orbital abort only (Mode IV or later), it is evident that a limited time is possible for a programmed simultaneous MPS burn with the T+256 Mode IV abort initiation. A variable amount of excess propellant is available for later burns and the dumping of Tug cryogens can be compensated by retaining an equivalent amount of potential delta V in the MPS propellants stored in the ET. It is noted, for example, that the normal mission insertion in Mode VI is made with about 4,500 lb of cryogenic propellants in the ET. In a total dump of Tug LO_2 and LH_2 on orbit,

53,000 lb or more of cryogens are dumped, and an equivalent amount of ET propellant retention must provide about 58,500 lb-sec of reduced thrust for Option 2. This delta V compensation is 9.42 fps of Orbiter velocity gain, based on a 200,000 lb Orbiter with payload.

The main engines consist of three 470,000 lb thrust units (1,410 K lb total) for normal thrust to orbit, or two engines may be operated at 512.3 K lb each at 109% EPL (1024.6 K lb total) for abort thrust to orbit. Therefore, with either normal thrust or emergency thrust, the thrust time reduction is 0.041 or 0.057 seconds to compensate for later propulsive cryogen dump delta V from Tug tanks. Calculation shows that 132.2 lb of MPS propellant is equivalent to 100% Tug cryogen dumping.

Delta V trimming is much simpler with OMS, if nonpropulsive OMS dumping is available, and the two 6,000 lb OMS thrusters would be operated for 4.88 seconds less time and would save 0.94% of inventory.

The four 900 lb RCS aft x-axis thrusters would reduce RCS operation time by about 16.3 seconds of net aft thrusting time to compensate for 100% Tug cryogen dumping.

7. The discussion under alternative No. 6 incorporates the data to define either an interrupted OMS or an interrupted MPS burn. The difference lies in the option to interrupt earlier, then to compute the necessary time, thrust level, and engine selection for a reduced later OMS or MPS burn after Tug dumping has been completed. Computation of the delta V gain from acceleration and time measurements to determine a reduced remaining delta V desired would then establish a new burn profile for the crew or Orbiter propulsion management system.

8. Use a computed abort delta V to bias the OMS, MPS, or RCS burn and thus compensate for abort dump delta V. This is a pre-flight computation. This is a refinement to alternative No. 7 and should be adequate to avoid interrupted burning for abort delta V compensation. This computation is based on a known weight of cryogen, a known helium pressure, and a known abort dump line diameter, thus yielding a known propulsion energy and thrust. If the abort dump initiation time and duration are known, the mass of the Orbiter will be known and the delta V can be calculated. For each particular mission, the total mass of Orbiter plus Tug plus payload will be known. Abort dumping after ET jettison therefore will impart a delta V which will be known before mission launch. A brief reduction of MPS, OMS, and/or RCS burns can be established before launch and programmed into the engine control system. The simplicity of this method leads to a recommendation that it be incorporated in the operational technique for the mission.

Computation of Abort Dump Delta V Compensation

$$\Delta V = \frac{g \times I_{sp} \; W_{prop}}{W_{orb}}$$

Required Total Negative Impulse = Total Tug Dump Positive Impulse

$$= 25 \text{ lb} \times 1{,}100 \text{ sec for } LH_3 + 50 \text{ lb} \times 620 \text{ sec for } LO_2$$

$$= 27{,}500 + 31{,}000$$

$$= 58{,}500 \text{ lb-sec}$$

$$\Delta V = \frac{g \times \text{Impulse}}{W_{orbiter}} = \frac{32.2 \times 58{,}500}{200{,}000}$$

$$= 9.42 \text{ ft/sec} = \text{Orbiter } \Delta V$$

RCS Compensation

4 x 900 lb thrust = 3,600 lb total RCS thrust available

Total impulse available = 2,806 lb x 289 second I_{sp} = 810,934 lb sec

Usec 58500/810,934 = 7.2% less of the RCS inventory or 202.4 lb less of 2,806 lb total. This is a desirable gain

Thrust time duration = $\frac{58,500}{3,600}$ = 16.25 seconds less time

Additional Commentary

MPS, DMS, RCS burn times were computed for Orbiter Mass above. OMS and RCS value are correct as shown for burns after ET jettison.

Since MPS burn occurs while the ET is on board, the mass should be with the empty ET plus 50% of the necessary ΔV propellant in the ET. This provides for a MPS burn that is shortened in duration.

Since Orbiter ΔV = 9.42 fps, calculate reduced MPS time from the total MPS thrust and average weight:

$$\text{Approx } W_{PROP} = \frac{\Delta V\ (W_{Orbiter} + W_{PL} + W_{TUG} + W_{ET} + W_{PROP}/_2)}{g \times I_{sp}}$$

$$= \frac{9.42\ (155 + 78 + \sim 0.1)\ \text{klb}}{32.2 \times 442.5}$$

$$= \frac{9.42 \times 288.1 \times 1000}{32.2 \times 442.5} = \underline{\underline{190.4}}\ \text{lb}$$

$$\text{Exact } W_{PROP} = \frac{9.42 \times 288.095 \times 1000}{32.2 \times 442.5} = \underline{\underline{190.5}}\ \text{lb}$$

This is comparable to the value of 132.2 lb computed previously from Orbiter weight alone, and applies to Alternatives #2 and #8. If an interrupted burn, Alternative #7, is used, more propellant will be expended for an earlier interruption period, because the ΔV gain per unit of expended propellent is less and must be made up later.

MPS Compensation

Three engines at normal thrust for 116 sec:

3 x 470 K lb x 116 = 163,560 K lb-sec

Two engines at EPL (109%) for 512 sec:

2 x 512.3 K lb x 512 = 524,595 K lb-sec

Orbiter Total Inventory = 688,155 K lb-sec

External Tank (ET) holds 1,555 K lb of propellant (usable):

$$\text{Then specific impulse } I_{sp} = \frac{688{,}155 \text{ K lb-sec thrust}}{1{,}555 \text{ K lb propellant}}$$

$$= 442.5 \text{ seconds}$$

$$W_{PROP} = \frac{\Delta V \times W_{ORB}}{I_{sp} \times q} = \frac{9.42 \times 200{,}000}{442.5 \times 32.2} = 132.2 \text{ lb of ET propellants}$$

$$\text{This is } \frac{132.2}{1{,}555{,}000} = 0.0085\% \text{ of the ET inventory}$$

Orbiter burn durations are computed as follows:

$$\text{Three engines @ 100\% Normal } \frac{58{,}500}{1{,}410{,}000} = 0.041 \text{ sec}$$

$$\text{Two engines @ 109\% Emergency } \frac{58{,}500}{1{,}024{,}600} = 0.057 \text{ sec}$$

OMS Compensation

$$\frac{\Delta V_{REQD}}{\Delta V_{AVAIL}} = \frac{9.42}{1000} = 0.94\ \% \text{ of total OMS inventory}$$

2 x 6000 lb thrust = 12,000 lb total OMS thrust

$$\text{Thrust time duration} = \frac{58{,}500}{12{,}000 \text{ lb}} = 4.88 \text{ seconds}$$

Delta V Benefit Due to Suborbital Abort Dump During Engine Operation

Objective. Assess the effect on ΔV as a result of dumping LO_2 during the main engine burn period after SRB jettison in a suborbital abort Mode III. Assume for this analysis that LO_2 dump is compatible with engine burn and that appropriate lines are available for such dumping.

Analysis. Two of the three main engines are assumed operable during an abort. These produce 2 x 470K lb. of thrust and are operated at EPL of 109% of nominal thrust, or 109% x 470K = 512.3K lb. each and 1024.6K lb. total. Two OMS pods will also be operating at 6K lb. thrust each. Total thrust, then, is 1024.6 + 12 = 1036.6K lb. The weight schedule as a function of launch events is shown in Table 6.4-1.

Table 6.4-1

SHUTTLE ASSEMBLY WEIGHT DATA

Ascent Weight	Orbiter	Ext. Tank	SRB	Total
Liftoff (T - 0)	207K	1633K	2327K	4167K
Pre-SRB Sep (T + 115)	207	1280	309	1796K
Post-SRB Sep (T + 116)	207	1280	-	1487K
Pre-ET Sep (T + 628.2)	207	78	-	285K
Post-ET Sep (T + 629.2)	207	-	-	207K
	Orbiter	**P/L**	**Cryogens**	**Total**
Orbiter Landing (T + 1343)				
Empty Cargo Bay	155K	-	-	155K
Min. Tug/PL Wt	155	25	-	180K
Mod. Tug/PL Wt	155	33	-	188K
Mod. Tug/PL Wt	155	25	8	188K

Averaging the weight at the beginning and end of thrust gives a value for ΔV calculation.

Option 1 has 43746 lb. LO_2 and 7954 lb. LH_2 (51,700 lb. total).

Option 1 (Rev.) has 50,850 lb. total at 5.5:1, or 43,027 lb. LO_2 and 7,823 lb. LH_2.

Option 2 has 55,500 lb. total at 6:1, or 47,571 lb. LO_2 and 7,929 lb. LH_2.

Option 3 has 54,450 lb. total at 5.5:1, or 46,073 lb. LO_2 and 8,377 lb. LH_2.

A 3 inch line will drain 7655 lb. of LH_2 in 410 sec @ 18.67 lb/sec; or 45,930 lb. of LO_2 in 630 sec @ 72.90 lb/sec. A 5 inch line will drain 7655 lb. of LH_2 in 130 sec @ 58.88 lb/sec; or 45,930 lb. of LO_2 in 200 sec @ 229.65 lb/sec.

Assume an early Mode III abort initiated at T + 121 secs., 40K lb. solar flight.

Case 1 Dump LO_2 only (assume an aft 3-inch line) 630 sec in 3 inch line, (507.2 sec during burn)

Initiation: T + 121, 1036.6K lb. thrust, 1487K lb. wt.

OMS burnout: T + 249.3, 1024.6K lb. thrust, 1174.2K lb.

Main engine burnout: T + 628.2, 0 thrust, 285K lb.

$$\Delta V = \frac{g\ I_T}{W_{AVG}} = \frac{32.2 \times (128.3 \times 1036.6K)}{(1487 - 1174.2)/2} + \frac{(378.9 \times 1024.6K) \times 32.2}{(1174.2 - 285)/2}$$

$$\Delta V_1 = \frac{32.2 \times 128.3 \times 1036.6K}{1330.6K} + \frac{378.9 \times 1024.6K \times 32.2}{728.6K}$$

$$= 3218.4 \qquad + 17,157.2$$

$= \underline{20,375.6}$ fps <u>if no LO_2 has been dumped.</u>

Now calculate the effect of LO_2 weight reduction by dumping:

LO_2 dumping reduces average wt. by $\frac{72.9 \text{ lb/sec} \times 128.3 \text{ sec}}{2} = 4626.5$ lb (avg)

1330.6K lb to 1324.0K lb during the first period and by $\frac{72.9 \text{ lb/sec} \times 378.2 \text{ sec}}{2} = 13{,}810.9$ lb (avg) from 728.6K lb to 714.8K during the second period.

$$\Delta V_2 = 3218.4 \times \frac{1330.6}{1324.0} + 17157.2 \frac{728.6}{714.8} = 3234.4 + 17488.4 = 20{,}722.8 \text{ fps}$$

Therefore, the change in velocity ($\Delta V_2 - \Delta V_1$) due to dumping the maximum of 36,874.8 lb. of LO_2 after SRB jettison and before main engine burnout through a 3-inch line is computed to be from 20,375.6 fps up to 20,722.8 fps -- a potential change of 347.2 fps or about 1.7%.

Note: A 2-inch line is provided for vertical fill/drain. The 3-inch abort dump line is for sub-orbital dumping.

The total LO_2 dumped during main engine burn, therefore, is 9253 lb + 27,621.8lb = 36,874.8 lb, or about 85.7% for Option 1, 77.5% for Option 2, and 80.0% for Option 3. These values of dumping are not available through the side 3 inch abort dump port without unporting (this occurs at about 45% max.). It is therefore assumed for this analysis that a switch to the aft LO_2 port is made at 40 45% LO_2 dump to fully utilize the main engine burn period.

A late mode III abort will occur when much less propellant is in the External tank but has less effect on velocity gain due to the smaller average weight reduction during burn. Figure 6.6.4- illustrates this effect and the greater gain due to early abort dumping.

The conclusion is reached that a small but significant delta V is available for early dump during main engine burn, and the greatest gain is obtained from dump initiation immediately after the abort decision is made.

7 OPERATIONAL COMPLEXITY

7.1 Methodology

Operational complexity may be defined as the number, duration, criticality and ease of completion of the combined events or functions that must be performed on the ground in order to accomplish the required Tug missions. Greater capability Tugs have increased complexity by virtue of their ability to perform payload retrieval through the addition of rendezvous and docking capability. The ability to handle spinning payloads and service orbiting payloads are further examples of added complexity due to increased mission capabilities. Low performance Tugs incur greater complexity by needing kick stages to achieve otherwise impossible missions. Autonomy level has a significant effect on complexity since it determines the proportion of events accomplished on the ground versus those performed on board the Tug. Complexity is also related to the number of critical events because contingency means must be provided for failure to successfully accomplish each critical event. Complexity increases with mission duration capability since a larger number of events are performed over the longer orbit stay times.

Evaluation of operational complexity does not readily lend itself to quantitative analysis. A qualitative examination of the applicability of the factors affecting complexity to a specific configuration is considered the most suitable approach to complexity assessment.

7 OPERATIONAL COMPLEXITY

7.1 Methodology

Operational complexity may be defined as the number, duration, criticality and ease of completion of the combined events or functions that must be performed on the ground in order to accomplish the required Tug missions. Greater capability Tugs have increased complexity by virtue of their ability to perform payload retrieval through the addition of rendezvous and docking capability. The ability to handle spinning payloads and service orbiting payloads are further examples of added complexity due to increased mission capabilities. Low performance Tugs incur greater complexity by needing kick stages to achieve otherwise impossible missions. Autonomy level has a significant effect on complexity since it determines the proportion of events accomplished on the ground versus those performed on board the Tug. Complexity is also related to the number of critical events because contingency means must be provided for failure to successfully accomplish each critical event. Complexity increases with mission duration capability since a larger number of events are performed over the longer orbit stay times.

Evaluation of operational complexity does not readily lend itself to quantitative analysis. A qualitative examination of the applicability of the factors affecting complexity to a specific configuration is considered the most suitable approach to complexity assessment.

7.2 Results/Conclusions

Option 3 includes two Tug configurations, an initial and a final. The initial configuration has low performance capability and no retrieval. Lack of rendezvous, docking, and spin-up capability and short mission duration contribute to a low level of complexity. The number of critical events is low due to limited mission capabilities and duration which also results in low complexity. The low autonomy level (IV) increases complexity but the overall level is considered low.

The final configuration has high performance capability, rendezvous, docking and spin-up capability, longer (six-day) mission duration and a resulting high number of critical events. All of these factors incur high complexity levels as does the low autonomy level (III). The overall complexity level is considered to be high.

8 NETWORK/COMMUNICATIONS REQUIREMENTS

Subsequent to Concept Selection the COR directed that tracking and communication network costs be removed from the flight operations cost estimates and that network utilization requirements in hours be calculated instead for both the 15 station ground net and a 5 station TDRS net.

Since this determination requires timeline information it was necessary to base the calculations on the four reference missions for which timelines have been developed. Computations were made for each reference mission based on the following groundrules:

a. Each main engine burn requires three ground contacts, i.e., uplink state vector update, downlink readiness report (with uplink burn enable or denial) and post burn downlink report. The times allotted for these contacts were 1, 2, and 2 minutes respectively.

b. During long coast periods a Tug status report will be required every 8 hours. This contact will require 2 minutes.

c. Ground tracking for orbit ephemeris determination is estimated to require a 3-minute track by each of 4 stations separated by at least a quarter of an orbit. Such a determination will be required prior to each main engine burn.

d. Other contacts required during payload deployment, rendezvous and docking were determined from the timelines. These consisted mainly of uplink sequence initiation and post operation reporting.

Using these groundrules, the mission timelines and the orbit profiles, calculations were made to determine the number of passes and contact times required for each reference mission, below and above 5000 KM for each of the option/configurations. Option 1 and Option 3 Initial are the same while Option 2 and Option 3 Final are also alike.

Using the number of missions of each type for each option derived from the mission capture analysis, the total number of passes and contact times for each mission category was calculated. Combining the mission category totals produced a grand total for the complete program Options 1, 2, 3

Initial and 3 Final. Since these are estimates of requirements, they are independent of the network considered and will be the same for the 15-station ground net, the 5 station TDRS net or the AFSCF net.

A summary of network utilization requirement estimates are shown on the following pages.

NETWORK OPERATIONS REQUIREMENTS

	Option 1	Option 2	Option 3 Initial	Option 3 Final
GEO-SYNCHRONOUS MISSION (REF MISSION α)				
PER MISSION				
BELOW 5000 KM				
NUMBER OF PASSES	29	29	29	29
CONTACT TIME (IN MINUTES)	70	70	70	70
ABOVE 5000 KM				
CONTACT TIME	49	128	49	128
NUMBER OF MISSIONS	113	105	82	131
TOTAL NUMBER OF PASSES	3277	3045	2378	3799
TOTAL CONTACT TIME (IN MINUTES)	13447	20790	9758	25938
PLANETARY MISSION (REF MISSION γ)				
PER MISSION				
BELOW 5000 KM				
NUMBER OF PASSES	37	37	37	37
CONTACT TIME	89	89	89	89
ABOVE 5000 KM				
CONTACT TIME	19	19	19	19
NUMBER OF MISSIONS	21	14	16	6
TOTAL NUMBER OF PASSES	777	518	592	222
TOTAL CONTACT TIME	2268	1512	1728	648
HIGH INCLINATION ELLIPTICAL MISSION (REF MISSION ε)				
PER MISSION				
BELOW 5000 KM				
NUMBER OF PASSES	28	28	28	28
CONTACT TIME	68	68	68	68
ABOVE 5000 KM				
CONTACT TIME	45	57	45	57
NUMBER OF MISSIONS	56	57	22	51
TOTAL NUMBER OF PASSES	1568	1596	616	1428
TOTAL CONTACT TIME	6328	7125	2486	6375

NETWORK OPERATIONS REQUIREMENTS
(Continued)

	Option 1	Option 2	Option 3 Initial	Option 3 Final
SUN SYNCHRONOUS POLAR MISSION (REF MISSION 8)				
PER MISSION				
BELOW 5000 KM				
NUMBER OF PASSES	31	31	31	31
CONTACT TIME	74	74	74	74
NUMBER OF MISSIONS	32	45	10	48
TOTAL NUMBER OF PASSES	992	1395	310	1488
TOTAL CONTACT TIME	2368	3330	740	3552
GRAND TOTAL NUMBER OF PASSES	6614	6554	3896	6937
GRAND TOTAL CONTACT TIME (IN MINUTES)	24411	32757	14712	36513

9 GUIDANCE UPDATE ANALYSIS

Analyses of the Guidance Navigation and Control (GNC) subsystem were made to determine placement accuracies at synchronous altitude. The analyses included the effects of the navigation uncertainties of the ground tracking system and the guidance errors accumulated during each of the main engine burns.

The ground tracking accuracy was analyzed by Aerospace Corporation using a digital computer simulation based upon the current range tracking accuracy of the STDN and SGLS equipment. The simulations established a need for four ground contacts in low earth orbit to determine navigation parameters of sufficient accuracy to accomplish the synchronous deployment mission. After four station contacts in low earth orbit, the navigation uncertainties were as follows:

	Postion (ft)	Velocity (ft/sec)
Radial	610	3.0
In Track	3040	0.6
Cross Track	610	0.6

An analysis of the ground station coverage was made to determine the number of possible contacts in the low orbit portion of the synchronous mission. The following stations were assumed in the analysis.

- MIL - Mila
- TAN - Tanamarine
- HAW - Hawaii
- GDS - Goldstone
- ROS - Rosman
- BDA - Bermuda
- ACN - Ascension
- BUR - Johannesburg
- QUI - Quito
- AGO - Santiago
- GWM - Guam

The results are summarized in Figure 9-1 and Table 9-1. The time scale origin is at Shuttle lift off. Based on the navigation analysis, the earliest opportunity for the phasing orbit burn is approximately one hour and forty minutes after launch. Depending on the longitude of the payload deployment, the first burn can be as late as 11 hours and 5 minutes.

Availability of tracking stations for the transynchronous orbit was also investigated. For this analysis only the five stations were utilized:

TYPICAL GROUND STATION COVERAGE

DUE EAST LAUNCH

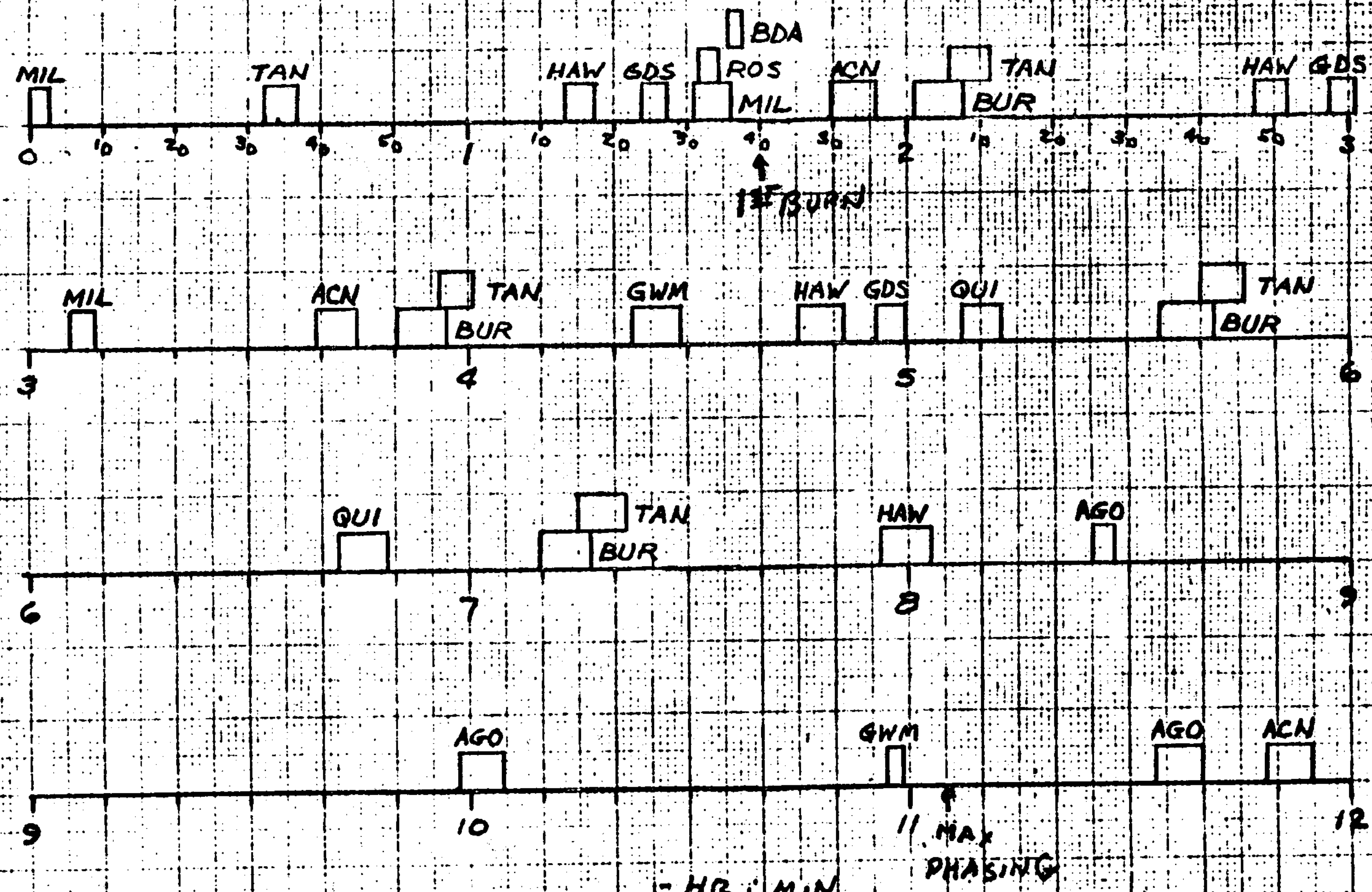


FIGURE 9-1

Table 9-1 (Page 1 of 2)

TRACKING STATION COVERAGE

(for 28.5° parking orbit)

Acquisition of Signal* HR:MIN	Loss of Signal* HR:MIN	Δt MIN	Station
0:00	0: 2.84	2.84	MIL
0:32.15	0:36.82	4.660	TAN
1:13.31	1:17.25	3.943	HAW
1:23.82	1:27.15	3.331	GDS
1:30.96	1:36.04	5.079	MIL
1:31.25	1:34.06	2.810	ROS
1:35.69	1:37.65	1.954	BDA
1:49.68	1:55.67	5.990	ACN
2: 0.93	2: 7.56	6.642	BUR
2: 5.89	2:11.10	5.216	TAN
2:47.10	2:51.90	4.800	HAW
2:57.31	3: 0.89	3.585	GDS
3: 5.51	3: 9.00	3.496	MIL
3:39.16	3:44.92	5.751	ACN
3:50.30	3:57.06	6.755	BUR
3:56.15	4: 0.80	4.650	TAN
4:22.30	4:28.96	6.658	GWM
4:45.06	4:51.07	6.011	HAW
4:55.61	4:59.56	3.951	GDS
5: 7.40	5:12.75	5.552	QUI
5:34.47	5:41.18	6.712	BUR
5:39.90	5:45.91	6.006	TAN
6:42.33	6:48.70	6.367	QUI
7: 9.88	7:16.65	6.769	BUR
7:15.02	7:21.77	6.750	TAN
7:56.28	8: 3.05	6.774	HAW
8:25.24	8:27.94	2.703	AGO
9:58.56	10: 4.52	5.957	AGO

Table 9-1 (Page 2 of 2)

TRACKING STATION COVERAGE

(for 28.5° parking orbit)

Acquisition of Signal* HR:MIN	Loss of Signal* HR:MIN	Δt MIN	Station
10:56.99	10:57.07	2.079	GWM
11:33.47	11:49.85	6.381	AGO
11:48.48	11:54.56	6.082	ACN
12:30.66	12:36.95	6.292	GWM
13: 8.66	13:14.38	5.713	AGO
13:23.60	13:29.65	6.055	ACN

*Based on minimum look angle of 5°

COOK - Vandenberg

GWM - Guam

BOSS - New Hampshire

IOS - Indian Ocean

HULA - Hawaii

Because the destination to geosynchronous altitude can be arbitrary, arrival longitude was made a variable parameter. Figures 9-2 through 9-6 show the tracking coverage for each of the five stations. Figure 9-7 shows the total coverage for all stations. These data were generated from an MDAC computer program called Trajectory Simulation Manual Program AD77. This program was originally developed as an analysis aid for SaturnSS-IVB stage preflight and post flight simulations. Results show that complete coverage is available after about 75 min. during the ascent. With continuous coverage available after 75 minutes, the navigation accuracy is as follows:

	Position (ft)	Velocity (ft/sec)
Radial	533	.189
In Track	3261	.130
Cross Track	15245	1.250

The guidance error sources are summarized in Table 9-2 and are based upon present strapdown hardware technology. The gyro errors are based upon uncalibrated drift rates which can be reduced considerably if the gyro is calibrated prior to the Tug launch. This error analysis is also based upon utilization of the star trackers for an attitude update prior to each main engine burn. The placement accuracy sensitivities to these error sources are summarized in Table 9-3 which indicates that accelerometers are the major source of error. The errors are based upon uncorrected targeting data.

Table 9-4 summarized the total placement accuracy for both the uncorrected and corrected cases. The corrected placement accuracy is based upon re-targeting of the final insertion burn using the navigation update during the transynchronous orbit. Both cases are well within the specified placement accuracies.

Table 9-2

GNC PLACEMENT ACCURACY

GUIDANCE ERROR SOURCES (3σ)

I	GYRO ERRORS	STRAPDOWN
	1. BIAS DRIFT	0.45 DEG/HR
	2. G-SENSITIVE DRIFT	0.06 DEG/HR
	3. G^2-SENSITIVE DRIFT	0.06 DEG/HR/G^2
	4. ALIGNMENT	60 SEC
	5. READ OUT ACCURACY AND LINEARITY	300 PPM (.03%)
II	ACCELEROMETERS	PENDULUM TYPE
	1. SCALE FACTOR	180 PPM (.018%)
	2. LINEARITY	90 PPM (.009%)
	3. ALIGNMENT	60 SEC
III	STAR TRACKER	STRAPDOWN
	1. INST. ACCURACY	45 SEC
	2. ALIGNMENT	60 SEC

Table-9-3

GNC PLACEMENT ACCURACY

GUIDANCE ERROR SENSITIVITIES (3σ)

	UNCORRECTED		
MAJOR ERROR SOURCES	IN TRACK	CROSS RANGE	RADIUS
GYRO DRIFT	9.2	4.9	3.1
GYRO READOUT	0.7	0.4	0.2
ACCELEROMETER READOUT	26.3	13.8	11.4
ALIGNMENT	3.6	2.0	1.3
	28.2	14.8	11.9

Table 9-4

GNC PLACEMENT ACCURACY

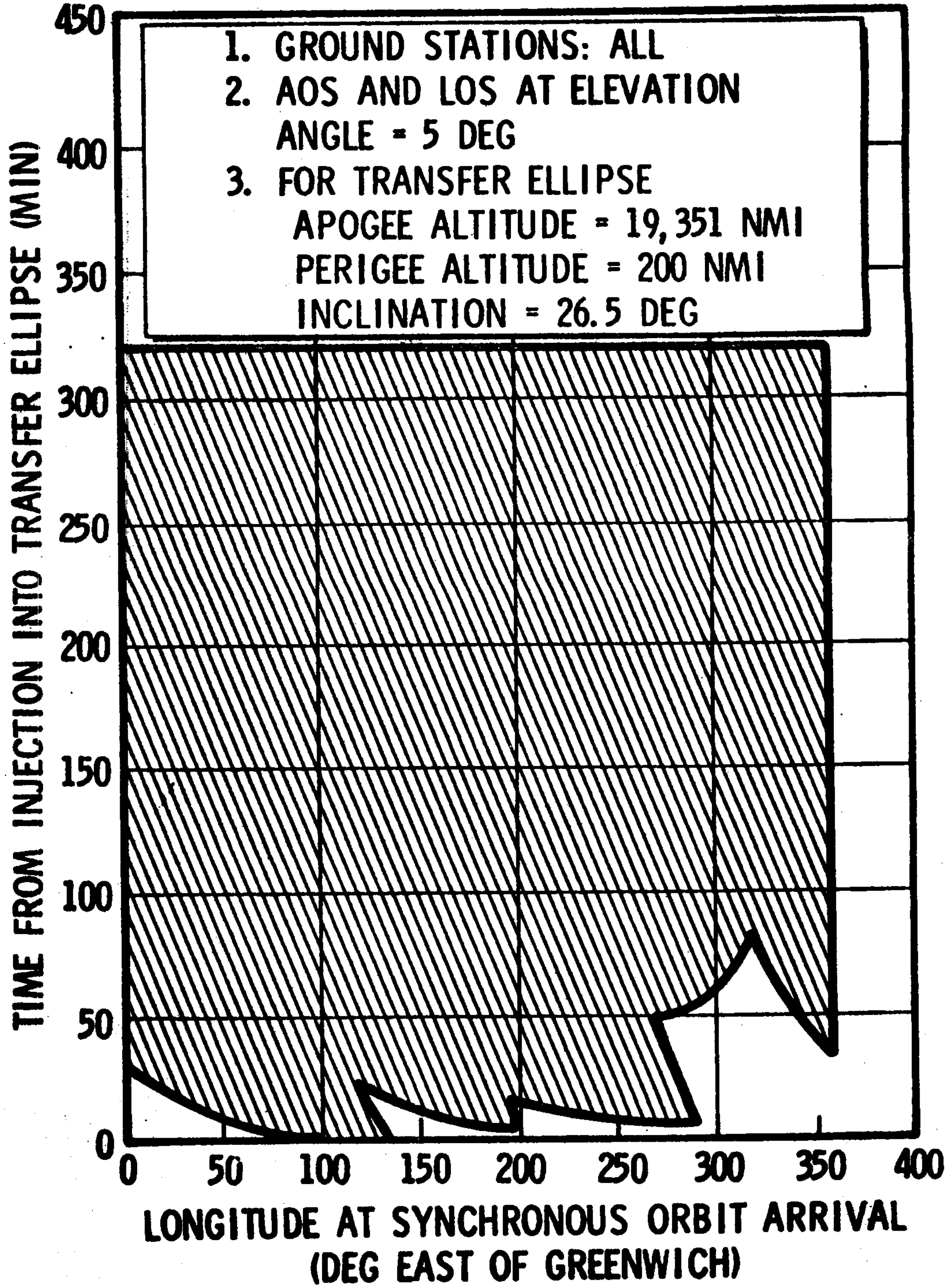
SYNCHRONOUS DEPLOYMENT ACCURACIES (NMI) (3σ)

	IN TRACK	CROSS RANGE	RADIUS	RSS
UNCORRECTED				
o GUIDANCE ERRORS	28.2	14.8	11.9	34.6
o NAVIGATION ERRORS	13.2	7.9	18.3	23.9
o RSS	31.1	16.8	21.8	41.5
CORRECTED				
o GUIDANCE ERRORS	Neg	Neg	Neg	Neg
o NAVIGATION ERRORS	0.5	2.5	0.1	2.55
o RSS	0.5	2.5	0.1	2.55

31658

Figure 9-7

GROUND STATION AOS AND LOS TIMES DURING TRANSFER TO SYNCHRONOUS ORBIT

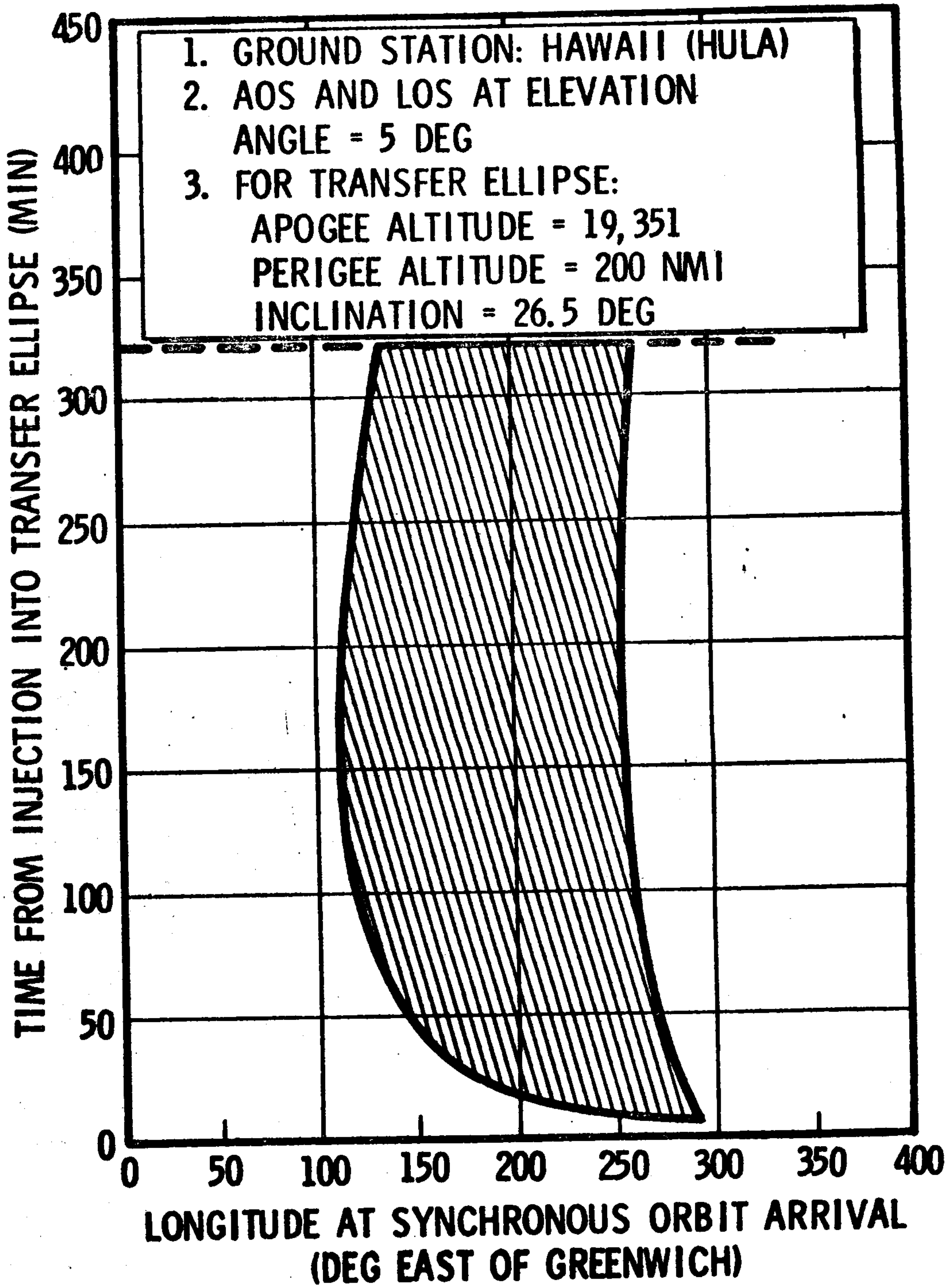


9-9

31664

Figure 9-6

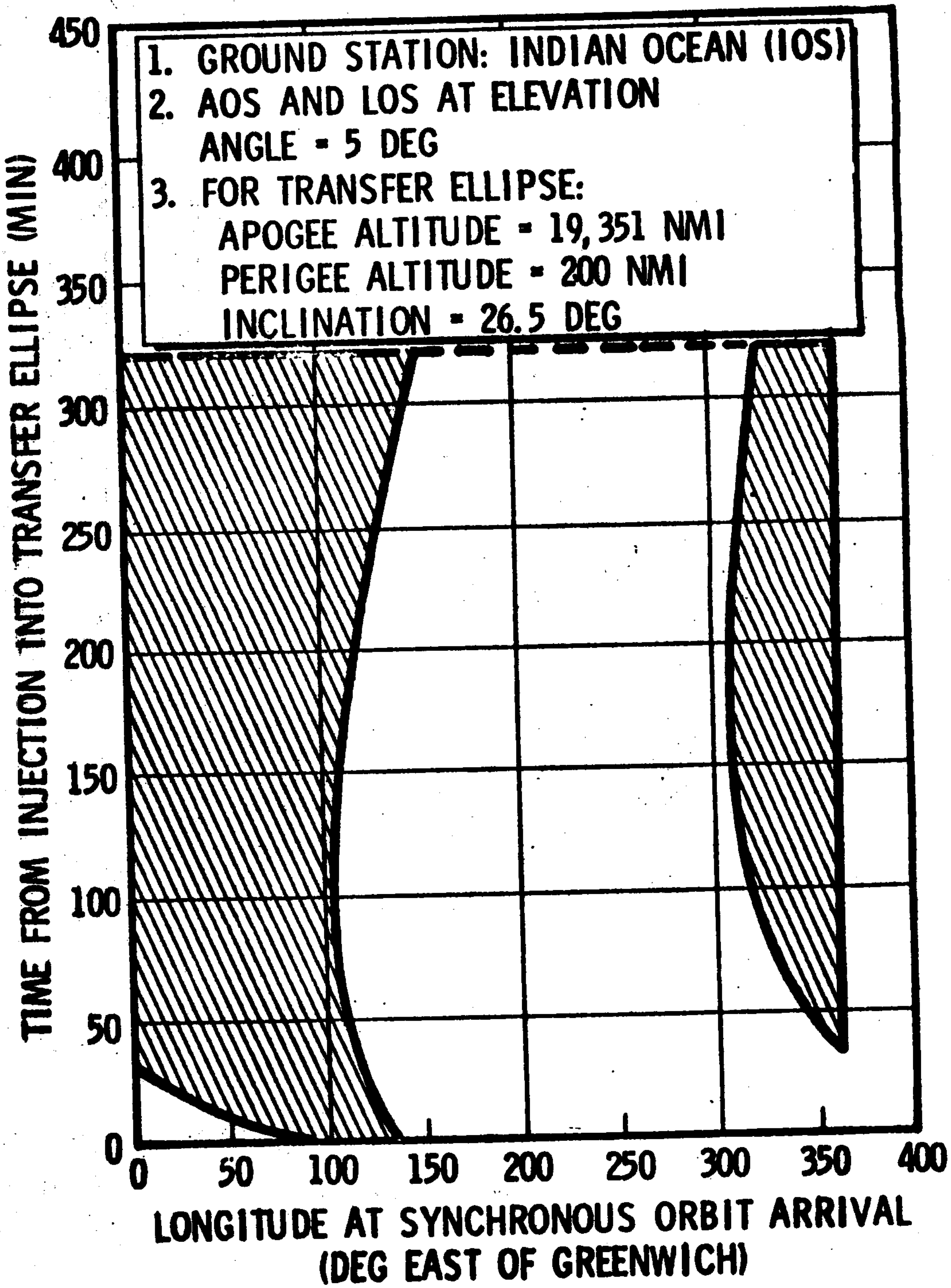
GROUND STATION AOS AND LOS TIMES DURING TRANSFER TO SYNCHRONOUS ORBIT



31663

Figure 9-5

GROUND STATION AOS AND LOS TIMES DURING TRANSFER TO SYNCHRONOUS ORBIT

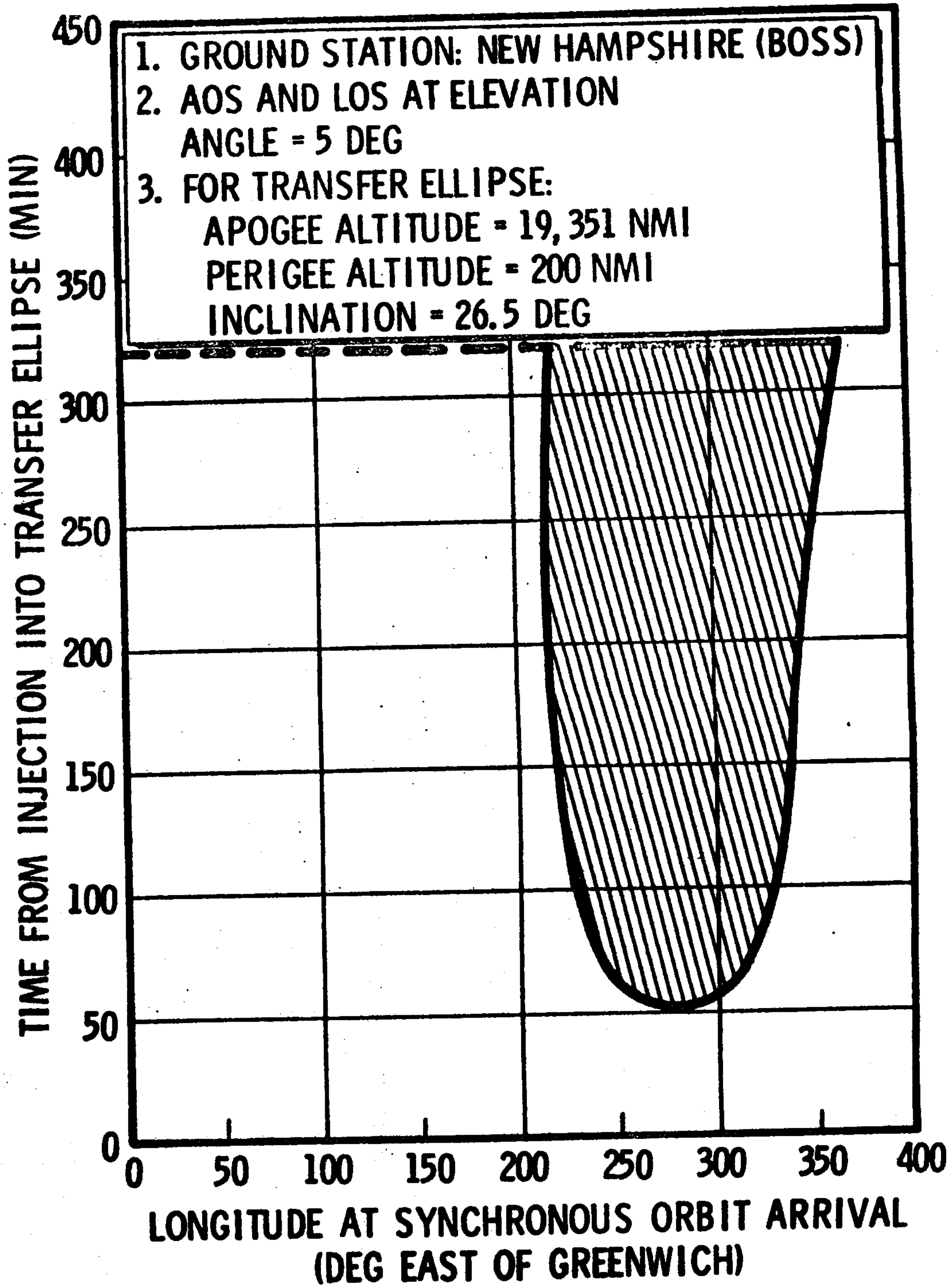


9-11

31667

Figure 9-4

GROUND STATION AOS AND LOS TIMES DURING TRANSFER TO SYNCHRONOUS ORBIT

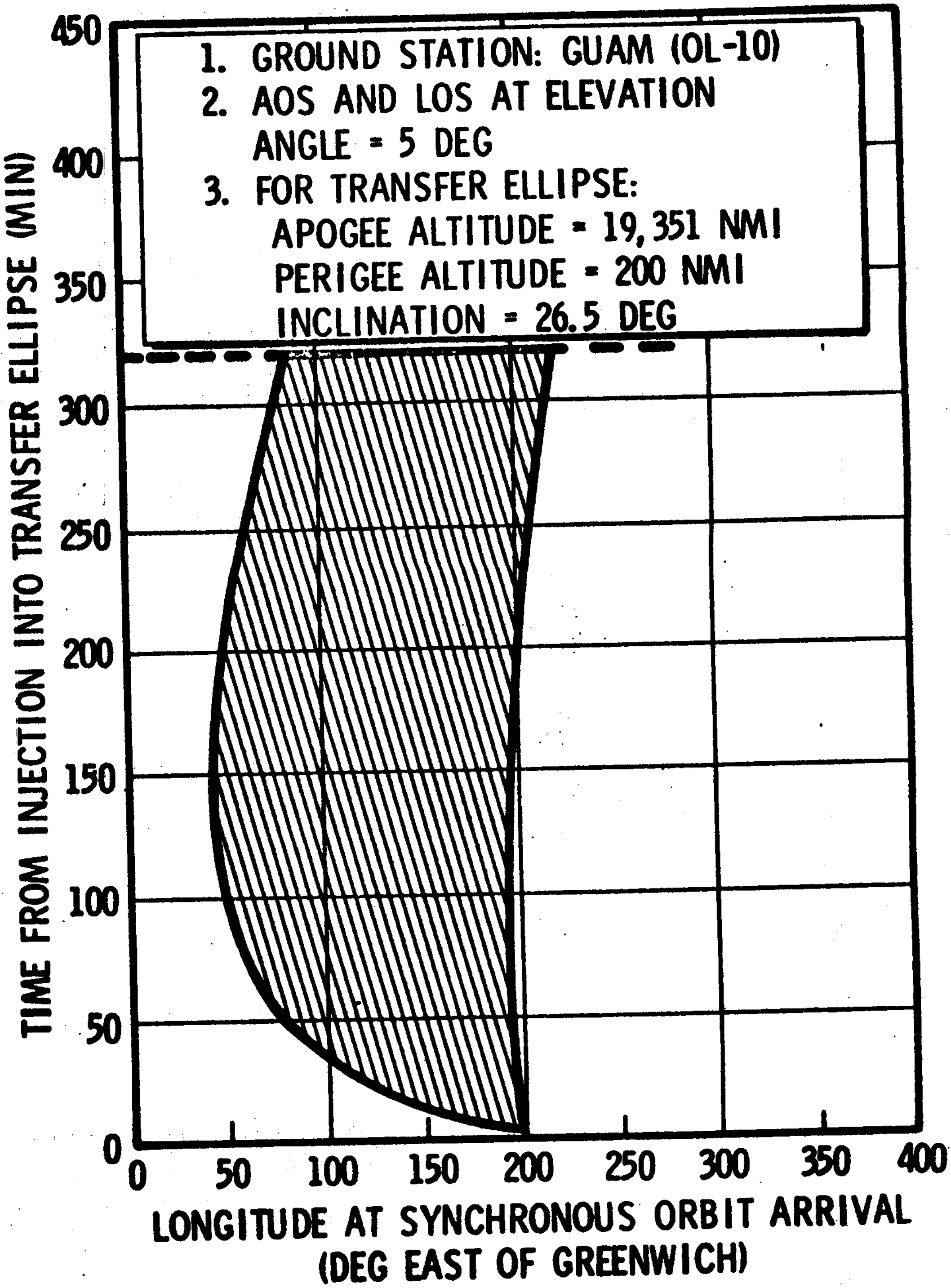


9-12

31657

Figure 9-3

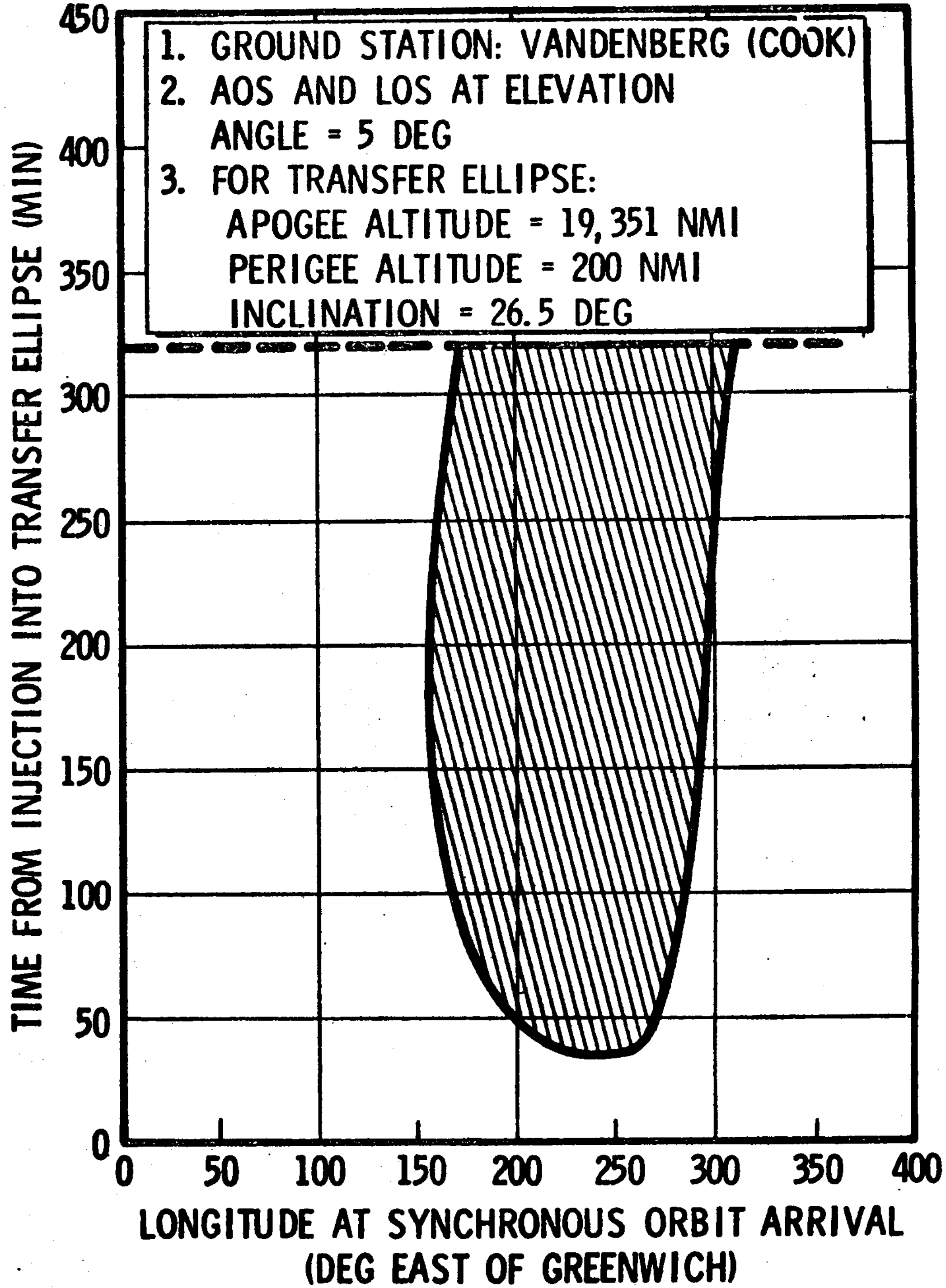
GROUND STATION AOS AND LOS TIMES DURING TRANSFER TO SYNCHRONOUS ORBIT



31655

Figure 9-2

GROUND STATION AOS AND LOS TIMES DURING TRANSFER TO SYNCHRONOUS ORBIT



10 RENDEZVOUS AND DOCKING

10.1 Rendezvous

Baseline rendezvous and docking operations for option 3F are initiated immediately following the injection burn into the target vehicle orbit. Targeting conditions for this burn are defined by vehicle placement accuracies and rendezvous sensor capabilities. Specifically, the targeting point must be chosen so as not to exceed the sensor maximum range and maximum scan capabilities for a given placement accuracy. This relationship between accuracy, targeting, and sensor acquisition is shown in Figure 10-1. The rendezvous sensor specified for these options is body fixed scanning laser radar with a maximum range capability of 100 nmi and a scan field of view of $\pm 15°$. The placement accuracy for both options is ± 10 nmi (3σ). Referring to Figure 10-1 meeting the $\pm 15°$ FOV requirements results in a targeting range of 50 nmi and a maximum range of 60 nmi., (Points A) which conforms to sensor capabilities. These range values may then be referred to Figure 10-2 which shows the rendezvous time/energy trade. For a 6 hour rendezvous interval (chosen to minimize out of plane correction requirements) the rendezvous ΔV required is between 26 and 39 ft/sec.

By relaxing the $\pm 15°$ acquisition scan angle condition rendezvous energy requirement may be reduced. Since the sensor is body fixed this requires maneuvering the vehicle to increase the effective scan FOV. As indicated in Figure 10-1, increasing this value to $\pm 45°$ results in an energy penalty of 2.3 ft/sec (equivalent ΔV) and a time penalty of 16.5 min and gives a nominal range of 25 mi and a maximum range of 35 mi (Points B). From Figure 10-2 this results in a rendezvous ΔV range of 12-21 ft/sec or a net nominal V reduction of 13.7 ft/sec.

Docking

The docking phase of the operation begins after braking the gross rendezvous velocity and at a range where docking port orientation can be detected. Following this detection a small ($\simeq$ 2 FPS) axial closing velocity is commanded. Subsequently a lateral circumnavigation velocity is commanded to maneuver the vehicle to the desired position along the extended docking port axis. The exact ranges at the start and finish of this maneuver are not critical but there is significant relationship between them. The initial range must be large enough that a range of 500-1000 ft is required. Figure 10-3 shows a simulation of the small lateral velocity input. Otherwise the sloshing excitation caused by lateral acceleration may jeopardize controllability. Simulation results indicate that a range of 500-1000 ft is required. Figure 10-3 shows a simulation of the terminal phase of such a maneuver.

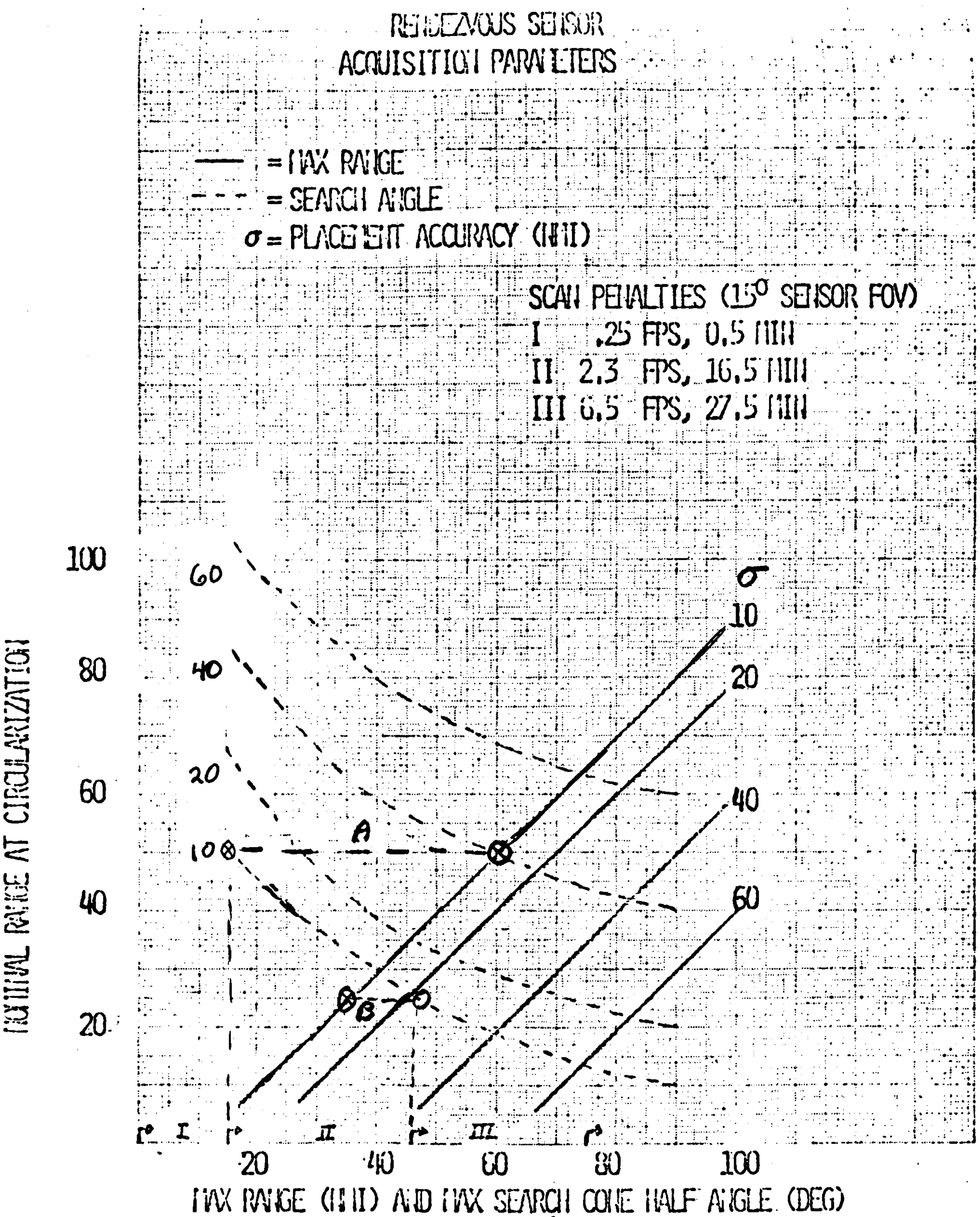
Once translational and rotational alignment with the docking axis has been attained final closure to contact is initiated. Nominal closure rate will be 1 fps and the vehicle attitude and translational position measured by the sensor and nulled about the docking axis. Simulation studies (including sloshing effects) have shown that this maneuver may be controlled within the following limits.

Axial Velocity	±.25 FPS
Rotation	±.20 deg
Translational Position	±.3 ft

As the Tug approaches the target there will be a minimum range condition at which closed loop tracking and homing ceases. From this point to contact the vehicle is inertially controlled based on the last measured closing conditions. Contact error conditions may then be determined based on the control accuracies given above, sensor accuracy, and the accuracy of the terminal inertial closure. The error values as defined in Volume 5 are:

Sensor Angular Measurement	.02 deg
Gyro Drift	.2 deg/hr
Accelerometer Null Error	$10 \mu g$
Sensor-IMU Alignment	.1 deg

The resultant contact error values are shown in Figure 10-4 as a function of loss of track range. For the sensor alone the minimum range capability is 5 ft giving a contact error of 5.7 in. However, geometric viewing constraint may increase this minimum range value. For example, with the sensor on the periphery of the Tug and a requirement to view the center of the target (probable for spinning targets) the minimum viewing range is 26 ft. Referring to Figure 10-4 this increases the contact error to 6.3 ft. However, the docking mechanism will tolerate errors of up to 10 in so that the minimum viewing range requirement indicated is 46 ft which seems achievable for any target geometry viewing conditions.


RENDEZVOUS SENSOR
ACQUISITION PARAMETERS
— = MAX RANGE
- - - = SEARCH ANGLE
σ = PLACEMENT ACCURACY (NMI)
SCAN PENALTIES (15° SENSOR FOV)
I .25 FPS, 0.5 MIN
II 2.3 FPS, 16.5 MIN
III 6.5 FPS, 27.5 MIN
NOMINAL RANGE AT CIRCULARIZATION
MAX RANGE (NMI) AND MAX SEARCH CONE HALF ANGLE (DEG)
σ
10
20
40
60
A
B
I
II
III

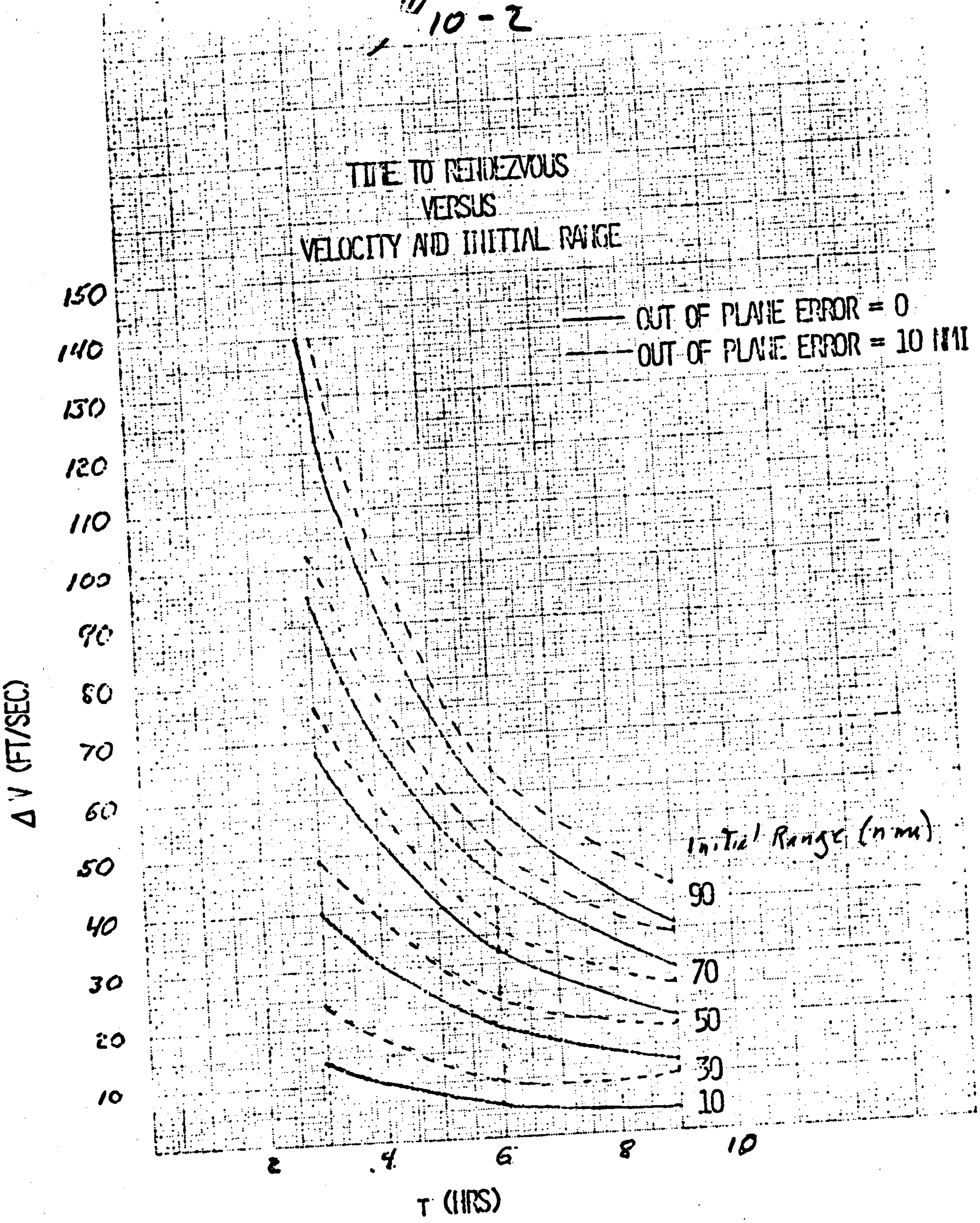
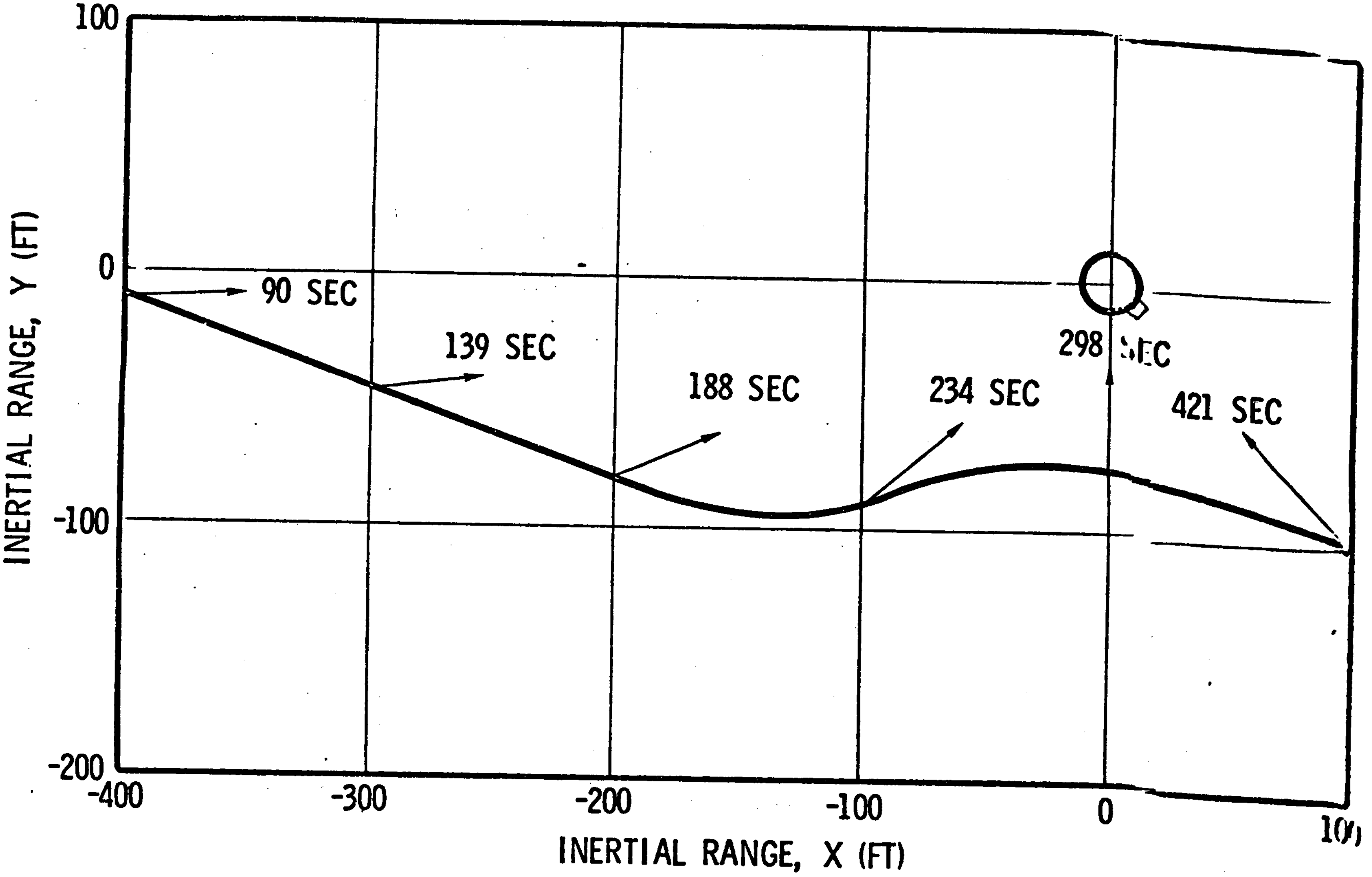

TIME TO RENDEZVOUS
VERSUS
VELOCITY AND INITIAL RANGE
OUT OF PLANE ERROR = 0
OUT OF PLANE ERROR = 10 NMI
Initial Range (n mi)
90
70
50
30
10
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ΔV (FT/SEC)
2
4
6
8
10
T (HRS)

FIGURE 2-13

~~SUCCESSFUL PHASE II MANEUVER~~

Docking Alignment Maneuver



10-3

10-6

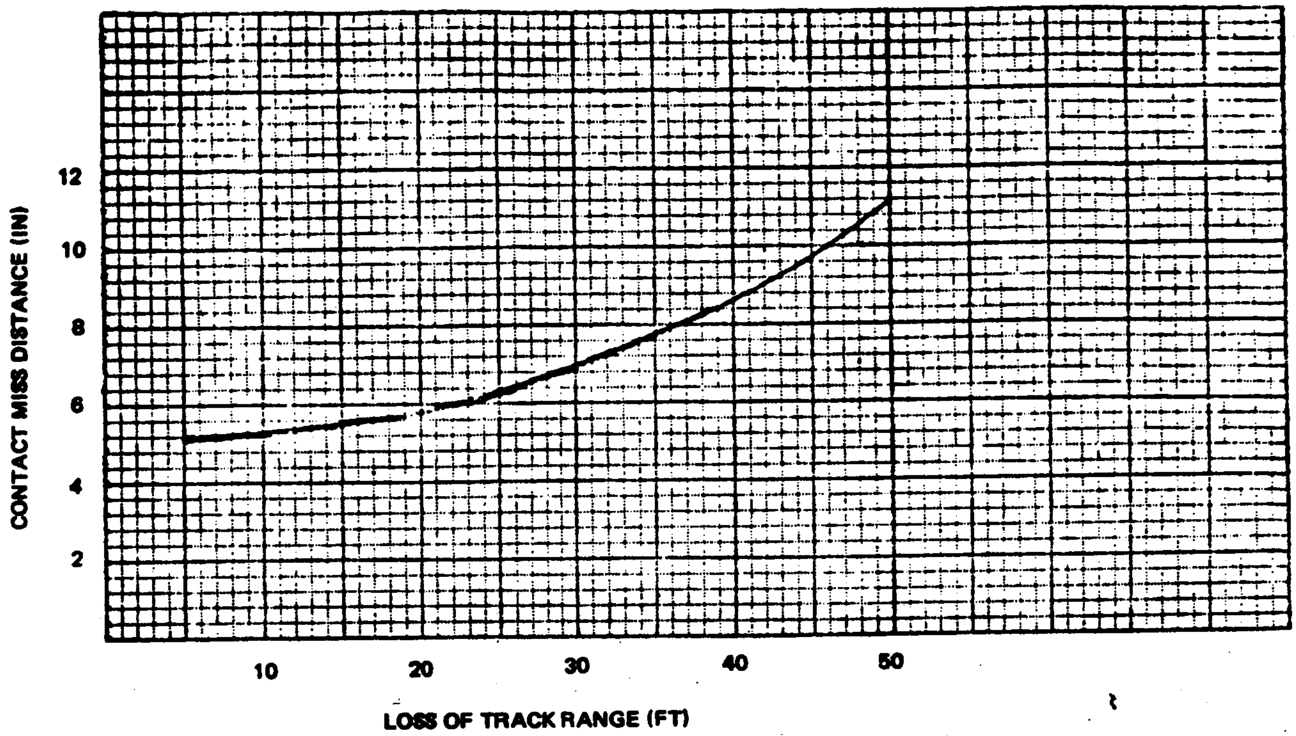


Figure 10-4. Minimum Track Range vs Docking Contact Miss

GROUND AND LAUNCH OPERATIONS

11.1 INTRODUCTION

The results of the ground and launch operations task include the detailed definition of all ground and launch operations activities, equipment, manpower and schedules at both the Eastern Test Range (KSC) and Western Test Range (VAFB) which are required to support both NASA and DOD Tub missions.

The overall study/program objectives which related to the ground and launch operations task are to

1) Low cost, development and operational, shall be a prime objective in the attainment of the Space Tug capability.
2) The Tug shall be fully reusable with a minimum life of 20 missions with a design goal of 100 missions.
3) The mission success reliability goal for the Tug shall be 0.97 minimum for all mission phases.
4) The Space Tug will be designed to be returned to earth in the Shuttle and be reused; reusability with minimized maintenance/ground turnaround cost is a design objective.
5) The Tug shall achieve resonable turn-around times and effective mission cost by reducing as much as possible, maintenance and inspection of systems, resulting in minimum subsystem replacements between flights.

The methodology of the ground and launch operations development for the cryogenic Tug basically consists of a ten step process. Each process step is described below and illustrated in Figure 1.

GROUND & LAUNCH OPERATIONS METHODOLOGY

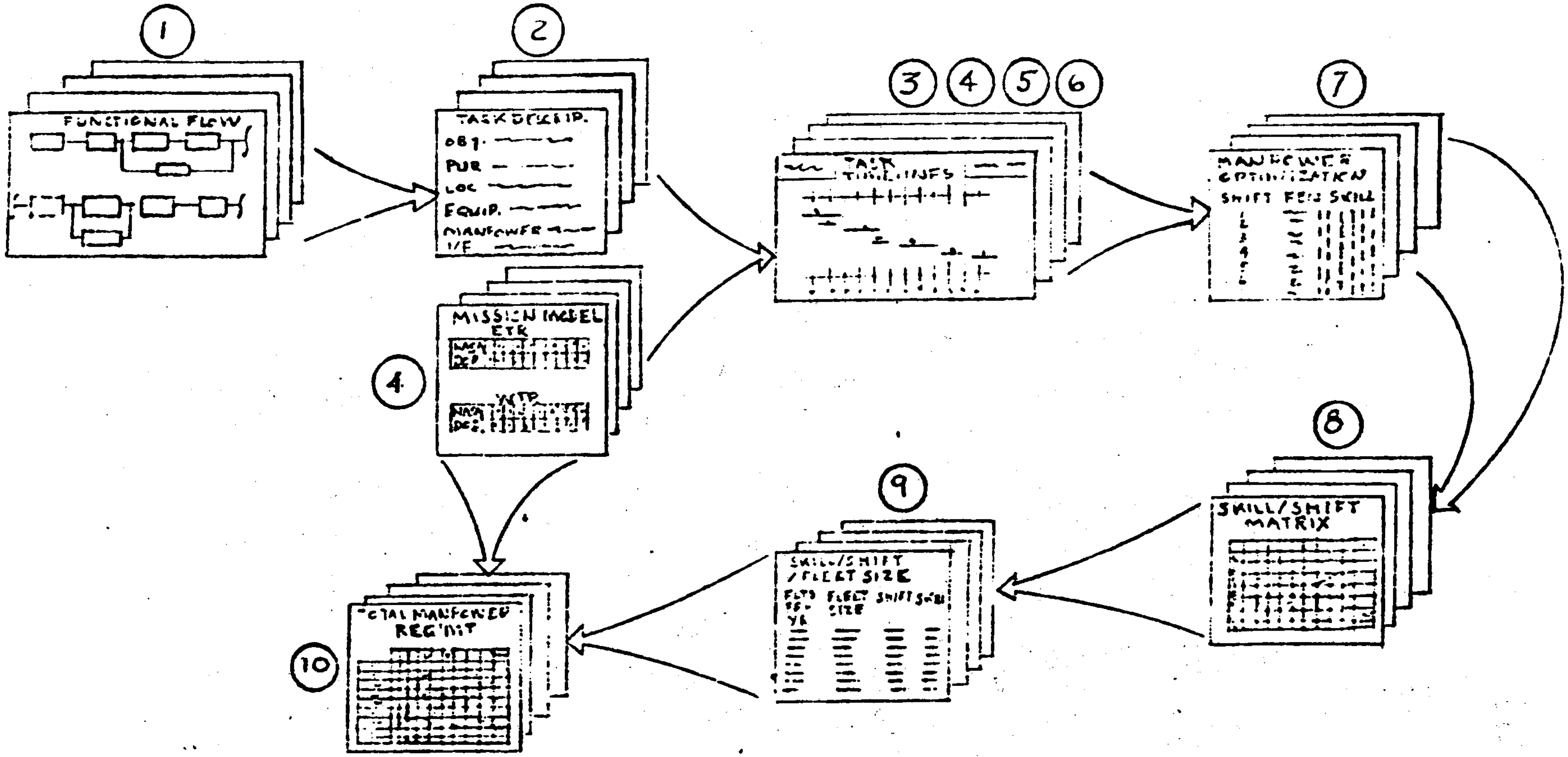


Figure 1

STEP 1: FUNCTIONAL FLOWS

For each Tug vehicle configuration option, top level functional flow diagrams were developed utilizing data and groundrules presented in the April 1973 data package to reflect the operatioanl requirements of each Tug option for the following items:

Flight Requirements (NASA/DOD)

- o ETR launches
- o WTR launches

Flight Composition

- o Tug (Basic)
- o Tub with Kick Stage

STEP 2: TASK DESCRIPTION SHEETS

As a prerequisite to the development of timelines and manloading, a task description sheet was constructed for each function identified in the functional flow diagrams of Step 1. These sheets were based on the guidelines and requirements contained in the April 1973 data package as well as MDAC experience in performing similar tasks on the SIV, SIVB, Thor, Thor Delta, and Skylab programs. The title, objective, purpose, location, required equipment, manpower and interface requirements for each functional task were specified on these sheets.

STEP 3: SUBTASK DEFINITION

Individual subtasks and their respective manpower allocation required to accomplish each functional task were defined utilizing the task description sheets of Step 2. Timelines were then developed to determine the overall time required for each functional task. These sheets were coordinated (and modified as necessary) with company engineers having appropriate checkout, maintenance and repair experience to insure the reasonableness of the time estimates and adequacy of the equipment defined.

STEP 4: MISSION MODEL ANALYSIS

The mission model for each Tug vehicle configuration option was analyzed for each launch site with regard to number of launches, user (NASA and DOD), flight composition, and mission type (deployment, round trip, etc.) The predominate Tug mission was then selected for detailed analysis and development of task timelines and sequences, and ground and launch operations manning requirements.

STEP 5: TASK TIMELINES AND SEQUENCE DEVELOPMENT

Based on the predominate Tug mission selected for each Tug vehicle configuration option in Step 4, the appropriate functional task timelines developed in Step 3 were assembled on a sequential hour by hour basis in a manner consistent with the functional flows for each respective Tug option.

STEP 6: TURNAROUND TIMES

Tug turnaround times were determined and top-level operational bar-chart flows were developed for each Tug configuration option based on the assembled timelines of Step 5. Statistical analyses of unscheduled maintenance requirements were included to provide adequate time for contingencies. By this means, the probability of meeting the turnaround time was established as .985.

STEP 7: SKILL PER SHIFT DETERMINATION

The task timeliness of Step 5 were evaluated on a task per flight basis and appropriate manpower skill requirements were optimized utilizing skill sharing techniques where possible to assure maximum utilization of individual workers.

STEP 8: MAXIMUM vs. MANDATORY SKILL BREAKDOWN

A skill per shift matrix was developed for each Tug vehicle configuration option utilizing the data derived in Step 7 in order to determine the maximum skill breakdown requirements and the mandatory skill breakdown requirements during those shifts whose operations are constrained by the Orbiter ground processing schedule.

STEP 9: MANPOWER vs. FLEET SIZE DETERMINATION

Based on the required on-orbit time and the turnaround time derived in Step 6 for each Tug option, liftoff to liftoff times were determined and the active Tug fleet size for any required launch rate was derived. Manpower levels for each required skill were then assigned on a per-shift basis accordingly.

STEP 10:

Utilizing the data generated in Step 9 and the number of required launches per year as specified in the traffic model for each Tug option, a total manpower per skill per shift per year matrix was developed.

The ground operations plan developed for each Tug vehicle configuration option provides the necessary supportive elements and associated data necessary to accomplish the study/program objectives and includes the following with pertinent results summarized in Figure 2.

1. Ground operations cost data for each WBS element
2. Manning requirements (skill categories, crew sizes by year based on launch rate for both ETR and WTR)
3. Active Tug Fleet size
4. Total program fleet size
5. Impact to Ground Operations in each applicable area for a two-year IOC delay for each Tug option
6. Operations constrained by the Orbiter
7. Ground turnaround operations description and timelines based on functional flow diagrams
8. Task descriptions for each Tug option
9. New, existing, or modified facilities and respective costs

10. GSE descriptions (type, amount, location, cost, etc.)

11. Maintenance/Refurbishment/Checkout impact on turnaround cycle

12. Spares planning

STUDY TASK	OPTION 1	OPTION 2	OPTION 3I	OPTION 3F	OPTION 3 COMPOSITE
1) GROUND OPS. COST DATA	ETR: $64.06 M WTR: $21.36 M	ETR: $53.07 M WTR: $22.86 M	ETR: $39.19 M WTR: $25.8 M	ETR: $57.84 M WTR: $7.93 M	ETR: $97.03 M WTR: $33.53 M
2) MANNING REQ'MTS	PEAK YEAR MANNING ETR: 159 WTR: 89	PEAK YEAR MANNING ETR: 250 WTR: 126	PEAK YEAR MANNING ETR: 188 WTR: 119	PEAK YEAR MANNING ETR: 245 WTR: 90	PEAK YEAR MANNING ETR: 290 WTR: 181
3) ACTIVE TUG FLEET SIZE	ETR: 3 MAX. 1 MIN. WTR: 1	ETR: 3 MAX. 2 MIN. WTR: 1	ETR: 3 MAX. 1 MIN. WTR: 1	ETR: 4 MAX. 2 MIN. WTR: 1	ETR: 4 MAX. 1 MIN. WTR: 1
4) TOTAL PROGRAM TUG FLEET SIZE	ETR: 8 WTR: 2	ETR: 7 WTR: 2	ETR: 2 WTR: 2	ETR: 6 WTR: 2	ETR: 8 WTR: 2
5) 2 YEAR IOC IMPACT	184 MAN-YR REDUCTION AT ETR	431 MAN-YR INCREASE AT ETR 189 MAN-YR INCREASE AT WTR	243 MAN-YR REDUCTION AT ETR	NO EFFECT	243 MAN-YR REDUCTION AT ETR
6) OPS. CONSTRAINED BY ORBITER	LANDING TO LANDING + 21 HRS L / O - 144 HRS TO L / O	LANDING TO LANDING + 21 HRS L / O - 144 HRS TO L / O	LANDING TO LANDING + 21 HRS L / O - 144 HRS TO L / O	LANDING TO LANDING + 21 HRS L / O - 144 HRS TO L / O	LANDING TO LANDING + 21 HRS L / O - 144 HRS TO L / O
7) GROUND TURNAROUND TIME (HRS)	ETR: 301 NASA 308 DOD WTR: 308 NASA 306 DOD	ETR: 328 NASA 341 DOD WTR: 328 NASH 328 DOD	ETR: 306 NASA 319 DOD WTR: 308 NASA 308 DOD	ETR: 328 NASA 341 DOD WTR: 324 NASH 324 DOD	ETR: 328 NASA 341 DOD WTR: 324 NASA 324 DOD
8) TASK DESCRIPTION DEVELOPMENT	56 FUNCTIONAL TASKS DEFINED	58 FUNCTIONAL TASKS DEFINED	55 FUNCTIONAL TASKS DEFINED	58 FUNCTIONAL TASKS DEFINED	58 FUNCTIONAL TASKS DEFINED
9) FACILITIES REQ'MTS DEFINITION	REQUIRES A NEW PAYLOAD PROCESSING FACILITY AT ETR & WTR	REQUIRES A NEW PAYLOAD PROCESSING FACILITY AT ETR & WTR	REQUIRES A NEW PAYLOAD PROCESSING FACILITY AT ETR & WTR	REQUIRES A NEW PAYLOAD PROCESSING FACILITY AT ETR & WTR	REQUIRES A NEW PAYLOAD PROCESSING FACILITY AT ETR & WTR
10) GSE DESCRIPTION	78 TYPES OF GSE EQUIP. REQUIRED	82 TYPES OF GSE EQUIP. REQUIRED	77 TYPES OF GSE EQUIP. REQUIRED	83 TYPES OF GSE EQUIP. REQUIRED	83 TYPES OF GSE EQUIP. REQUIRED
11) MAINT / REFURB / CHECKOUT IMPACT ON TURNAROUND	MAINT / REFURB / CHECKOUT REQUIRES 75 HRS	MAINT / REFURB / CHECKOUT REQUIRES 75 HRS	MAINT / REFURB / CHECKOUT REQUIRES 75 HRS	MAINT / REFURB / CHECKOUT REQUIRES 75 HRS	MAINT / REFURB / CHECKOUT REQUIRES 75 HRS

Figure 11-2. Ground and Launch Operations Summary

II.2 Groundrules and Assumptions

The groundrules and assumptions which influence the development of the ground and launch operations planning are summarized as follows.

II.2.1 General

Objectives

- Low cost, development and operational, shall be a prime objective in the attainment of the Space Tug capability. (Data Package)

- The Tug shall achieve reasonable turn-around times and effective mission cost by reducing as much as possible maintenance and inspection of systems, resulting in minimum subsystem replacements between flights. (Data Package)

Facilities

- The Tug shall be capable of being serviced by the standard STS environmental, power, and fluids service facilities. Unique support requirements shall be provided by the Tug contractor. (Data Package)

- Facilities are required at WTR and KSC to support pre-flight and post-flight processing of the Tug. The facilities shall provide standard services, e.g., power, fluid, and environmental control.

II.2.2 Ground Systems

Ground Support Equipment

- The need for specialized post-flight servicing equipment shall be minimized. (Data Package)

- Reconfiguration on the (Orbiter) access panels will be charged to the Tug as will the unique AGE required for the checkout or test procedures. (Data Package)

Checkout

- The Tug shall utilize the automatic checkout AGE for pre-flight and post-flight checkout and test procedures. (Data Package)

- When installed in the orbiter cargo bay on the launch pad, Tug access to the automatic checkout system shall be via the standard Tug to orbiter interfaces. (Data Package)

- Unique Tug checkout or test requirements will be supported from the Mobile Payload Service Tower through orbiter interface panels. (Data Package)

- The Tug shall also be capable of interfacing with a secure SGLS compatible communications system when secure data transmissions are required to support Tug processing procedures. (Data Package)

11.2.3 Operation Plan

Receipt

- The Landing Facility will be utilized to accept initial delivery of the Tug at the launch site via Logistic aircraft. (Data Package)

- The Landing Facility will provide for post-flight recovery of the Tug via the Orbiter vehicle. (Data Package)

- New Tugs will be delivered to the launch site by air. (Data Package)

- The aircraft will be off-loaded with contractor furnished transportation and handling equipment. (Data Package)

- The Tug off-loading from aircraft will be accomplished by a launch site crew who will remove the vehicle from the aircraft and deliver it to the PPF at WTR or the Tug Processing Facility at KSC. (Data Package)

- Any specialized shipping equipment will be removed following receipt (at the PPF or TPF) and returned to the contractor. (Data Package)

- A new Tug will be subjected to a visual and functional inspection for shipping damage. (Data Package)

Storage

o At the completion of the initial receiving inspection operation or the maintenance cycle, the Tug will be prepared for storage in an operational condition if not scheduled for a mission. (Data Package)

Refurbishment

o At WTR, the DOD will perform postflight maintenance and refurbishment operations for both DOD and NASA Tugs in a dedicated DOD payload processing facility. (Data Package)

o At KSC, NASA will perform postflight maintenance and refurbishment for both DOD and NASA Tugs in the NASA Tug Processing Facility. (Data Package)

o At WTR, the Payload Processing Facility supports the receipt, storage, refurbishment and pre-flight processing and checkout of the Tug, including, if required, mating and integration of the Tug with a spacecraft. (Data Package)

o At KSC, the Tug Processing Facility supports the receipt, storage, refurbishment and pre-flight processing and checkout of the Tug, including, if required, mating and integration of the Tug with a spacecraft. (Data Package)

- Tug activities will include performance of required corrective actions identified during the preceding mission and those identified during the inspection, handling, and service activities of the turnaround cycle. (Data Package)

- Predictable maintenance using trend analysis data derived from on-board systems will be emphasized to the maximum extent possible. (Data Package)

- Preventive maintenance actions will be systematically carried out to provide for the general care of the Tug. (Data Package)

- Inspection

  - The Tug will be subjected to a detailed visual inspection of all accessible spaces and installations on arrival in the Tug Maintenance Facility. (Data Package)

  - Accessible Inspection will include the following:

    a. Vehicle structure condition

    b. Security of subsystem installation

    c. Containment of fluids

    d. General condition of vehicle

    e. General cleanliness of vehicle (Data Package)

- Inspection of spaces not readily accessible, and the non-destructive evaluation of structural and mechanical equipment, will be completed on a periodic basis depending on the number of missions completed and total flight hours. (Data Package)

- Inspections will be performed throughout the maintenance and checkout cycle on a progressive basis to insure vehicle integrity. (Data Package)

o Preplanned preventive maintenance will be accomplished during every maintenance operation. Preventive maintenance will be scheduled for periodic accomplishment on equipment not requiring service after every flight. (Data Package)

o Unscheduled maintenance will be accomplished on an "as required" basis. (Data Package)

Preflight Processing

o Refurbished DOD Tugs at KSC will be routed to a dedicated DOD payload processing facility for preflight processing by DOD personnel. (Data Package)

o Premate activities will be to establish and test the interface (mechanical, electrical, and fluid) between the Tug and the spacecraft and/or Orbiter. (Data Package) o Testing (Data Package)

- A Space Ground Link System (SGLS) compatible communications link will be provided between the Tug and Spacecraft Mating Facility and the Satellite Control Facility to support integrated systems tests.

- The Shuttle Integration and Mating Facility will provide the capabilities to perform Tug and/or Spacecraft health checks.

- New Tugs will undergo integrated systems tests prior to premate operations.

- Systems containing a reported malfunction will be tested to verify and isolate the discrepancy.

- When the required maintenance actions on the vehicle have been completed, all subsystems that have been entered for maintenance purposes will be individually checked out and verified.

- At the completion of the maintenance and checkout procedures, the Tug will undergo integrated system tests to verify flight readiness.

o Tug-to-Spacecraft Mating (Data Package)

- The Tug-to-Spacecraft mating will be performed in the PPF for DOD spacecraft, and in the TPF for NASA spacecraft at KSC.

- The Tug-to-Spacecraft mating will be performed in the PPF at WTR.

- -- Tug-to-Spacecraft mating operations are completed with interface verification and integrated system tests.

- Spacecraft cleanliness shall be maintained and verified following the mating activities.

o Installation in Orbiter (Data Package)

- Installation of payloads (Tug and/or spacecraft) in the Orbiter cargo bay is currently baselined to be accomplished in the Orbiter MCF while the Orbiter is in the horizontal position.

- Installation in the vertical position using the payload changeout facilities provided at the launch pad shall be utilized for contingencies only.

- The Orbiter MCF provides the capability for installation of the Tug or Tug/spacecraft assembly in the Orbiter cargo bay.

- The electrical and mechanical mating operations are performed and interface verified through AGE/GSE and the mission operator console.

o Storable Propellants (Data Package)

- The Storable Propellant Facility provides the capability for loading storable propellants into the Tug for preflight operations.

- The Storable Propellant Facility provides the capability for residual propellant removal and Tug decontamination.

o Environment (Data Package)

- The Shuttle Integration and Mating Facility will provide the capability to maintain the Orbiter cargo bay environmental condition within the requirements of the Tug and/or spacecraft.

o Servicing (Data Package)

- Facilities at the launch pad will provide the following for the Tug:

  a. Propellant Fill and Drain

  b. Emergency Propellant Drain

(Cont.)

c. Pressurant Fill and Vent

d. Communications Links for Status Monitoring

e. Subsystem Tests

f. Integrated System Test

- Storable Tug propellants and pressurants may be loaded either on the pad while the Tug is in the cargo bay or at some remote tanking facility prior to Tug/Shuttle integration

o **Pad Hold** (Data Package)

- If a hold is required after cryogenic propellant loading, the propellant loading system will be configured for a replenish mode of operation.

- During a hold period, selected airborne and AGE/GSE parameters will be monitored to ascertain the Tug system status.

o **Backout** (Data Package)

- Cryogenic propellant detanking will be accomplished via the propellant loading system GSE.

- During detanking, individual drain lines will be utilized for the Tug and Orbiter, and this will be accomplished simultaneously.

- Monitoring of detanking will be performed remotely.

- The removed payload (Tug and/or spacecraft) will be returned to the PPF or the TPF.

Postflight

o Safe and Purge (Data Package)

- At the safe and purge area, residual propellants are removed and the propellant tanks purged.

- At the safe and purge area, high pressure gas systems are vented.

- At the safe and purge area, the unexpended ordnance is disarmed.

- Thermal control of the Tug and/or spacecraft will be maintained during safe and purge procedures.

o Removal (Data Package)

- The Orbiter MCF provides the capability for removal of the Tug or Tug/spacecraft assembly in the Orbiter cargo bay.

- For contingencies, the Mobile Payload Service Tower will support payload removal at the launch pad.

- Security procedures will be required if a classified spacecraft is to be removed and only spacecraft processing personnel with the required security clearance will be allowed to perform this task.

Transportation -

o Classified Spacecraft (Data Package

- A security patrol will accompany a classified spacecraft during all transportation.

- If a classified spacecraft is to be transported, procedures will be employed to ensure physical security.

o Cleanliness (Data Package)

- Cleanliness will be maintained throughout preflight transfer.

- The Tug will be enclosed in a protective cover to maintain its cleanliness during transport to the spacecraft mating area.

11.2.4 Shuttle Guidelines

Preflight Processing

o Installation

- The payload will normally be installed with the Orbiter in the horizontal position. (JSC 07700)

- The access, removal, and loading of payload items on the pad must be accomplished no later than TBD hours prior to launch. (JSC 07700)

O Checkout and Testing

- Detailed acceptance testing of each payload subsystem is performed prior to installation. (JSC 07700)

- A launch readiness checkout will be conducted at the launch pad prior to prelaunch servicing and propellant loading. (JSC 07700)

- Checkout of the payload for pre-launch operations makes use of the ground checkout equipment and the onboard checkout command decoder for hardwired uplink commands. (JSC 07700)

- Conditioned air purge will be supplied to the payload bay at the launch pad, up to 30 minutes prior to propellant loading. (JSC 07700)

  a. 0 to 200 lbs/min.

  b. 45°F to 120°F within ±2°F of desired

  c. Class 100,000

  d. 0 to 43 grains/pound of air

- From 30 minutes prior to propellant loading, up to liftoff, a GN_2 purge (for the payload bay) will be supplied. (JSC 07700)

  a. 0 to 200 lbs/min.

  b. 45°F to 120°F, within ±2°F of desired

  c. Class 100,000

  d. 0 to 1 grain/pound of GN_2

Post-Flight Processing

0 The payload will normally be removed with the orbiter in the horizontal position. (JSC 07700)

11.2.5 WORKING GROUP GUIDELINES

Launch Rates

- Use a uniform launch rate in a given year. (G & L OPS PANEL)

Shuttle Compliance

- The Tug ground operations must be compatible with the Baseline KSC Space Shuttle Processing Flow. (G & L OPS PANEL)

- The capabilities and constraints for the Space Shuttle are summarized on Figure 11.2.5-1 (G & L OPS PANEL)

- Manloading requirements are based on work schedule
  - a. 8 hr/shift
  - b. 2 shifts/day
  - c. 5 days/week

Cleanliness

- It is recommended that Tug cleanliness be compatible with that provided in the Orbiter payload bay (G & L OPS PANEL)

Security

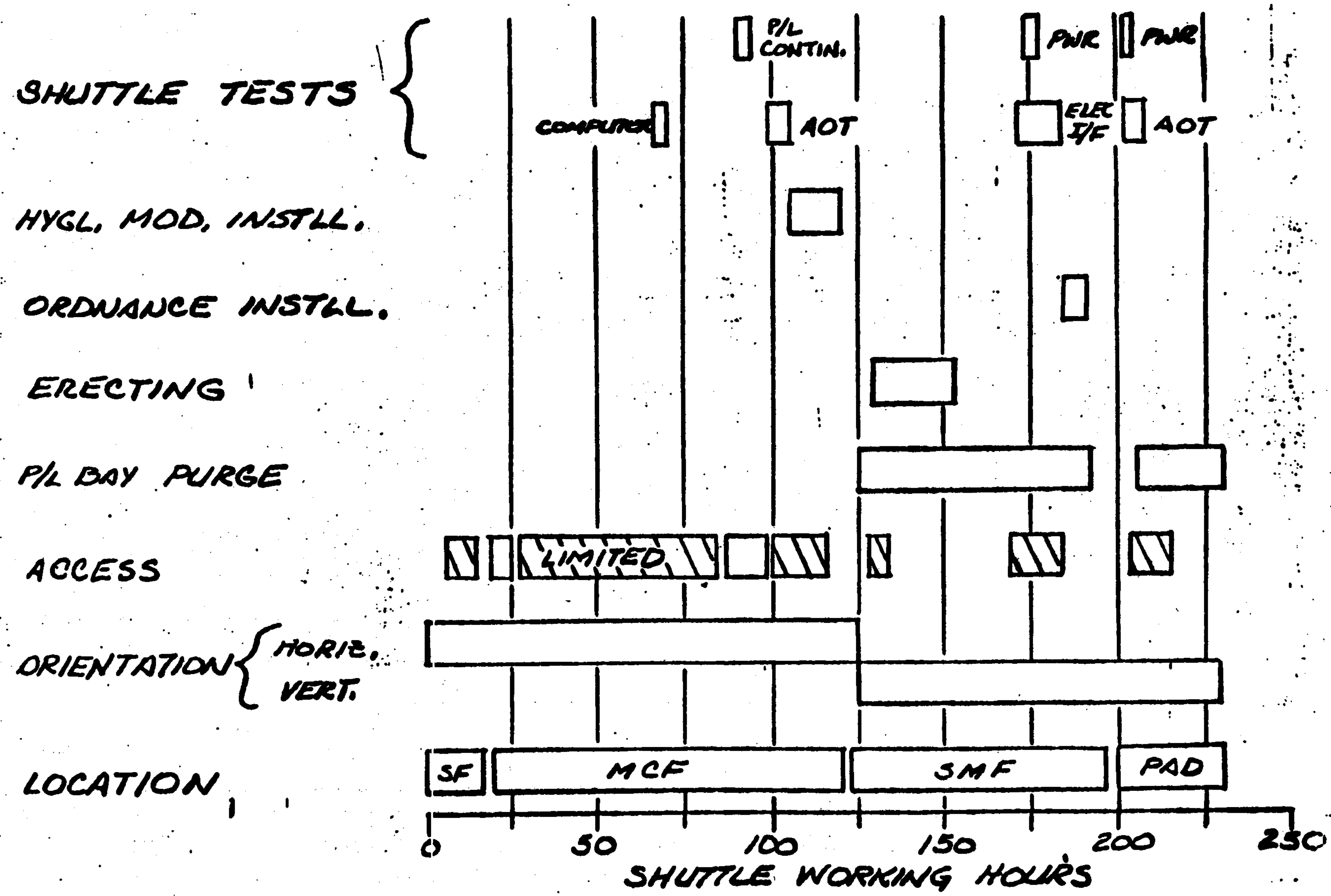
- Security at WTR should be treated the same as KSC. (G & L OPS PANEL)

Alternate Site

- Alternate sites will not be available for the Tug Program. (Cost Panel)

FIGURE 11.2.5-1

SHUTTLE CONSTRAINTS



11.3 Ground Operations Plan

6

11.3.1 Section 6.11.3 provides a baseline ground operations plan to support the DOD-SAMSO/NASA-MSFC Option 3 Space Tug. A pre-IOC operations plan, top-level functional flows, operations sensitivities to Tug configurations, operations constrained by the Orbiter, ground turn-around operations, task descriptions, and manning requirements are provided in this plan.

The plan identifies the ground operational requirements for the Tug, including interfaces and interactions of DOD and NASA operations at ETR (KSC) and WTR (VAFB).

A two-year IOC delay within the Option 3 Space Tug program has the following effects on active Tug fleet size and total manpower requirements.

Active Tug Fleet Size

a) Option 3I: The active fleet size in program years 1980 and 1981 is reduced from 1 to zero at ETR.

   A two-year IOC delay has no effect on the active Tug fleet size at WRT.

b) Option 3F: A two-year IOC delay has no effect on the active Tug fleet size at either ETR or WTR.

Total Manpower Requirements:

a) Option 3I: The total manpower requirements in program years 1980 and 1981 are reduced from 75 to zero and 168 to zero people, respectively, for a net reductions of 243 man years at ETR.

   A two-year IOC delay has no effect on total manpower requirements at WTR.

b) Option 3F: A two-year IOC delay has no effect on total manpower requirements at either ETR or WTR.

11.3.2.1 Activation and Verification Operations for ETR and WTR

The schedule summarizing the activation and verification operations for ETR and WTR is presented in Figure I. This option includes reverification of both sites for the final configuration phase of the program.

11.3.2.1.1 Eastern Test Range

The activation of ETR will begin 36 months prior to the initial IOC date, 24 months prior to the initiation of the Tug Flight Test Ground Operations of the initial configuration. During the first 20 months, the site configuration will be completed and activated. In the 21st through the 24th months, the facilities and equipment will be verified utilizing the Space Tug simulator and the Shuttle/Tug Interface simulator.

The final ETR verification and certification will be completed from the 25th through the 36th months utilizing the first flight vehicle. The personnel utilized during this phase of the program will establish, revise, and finalize the procedures and plans for the operational phase of the program. These personnel will form the nucleus of the operational ground crew compliment at ETR.

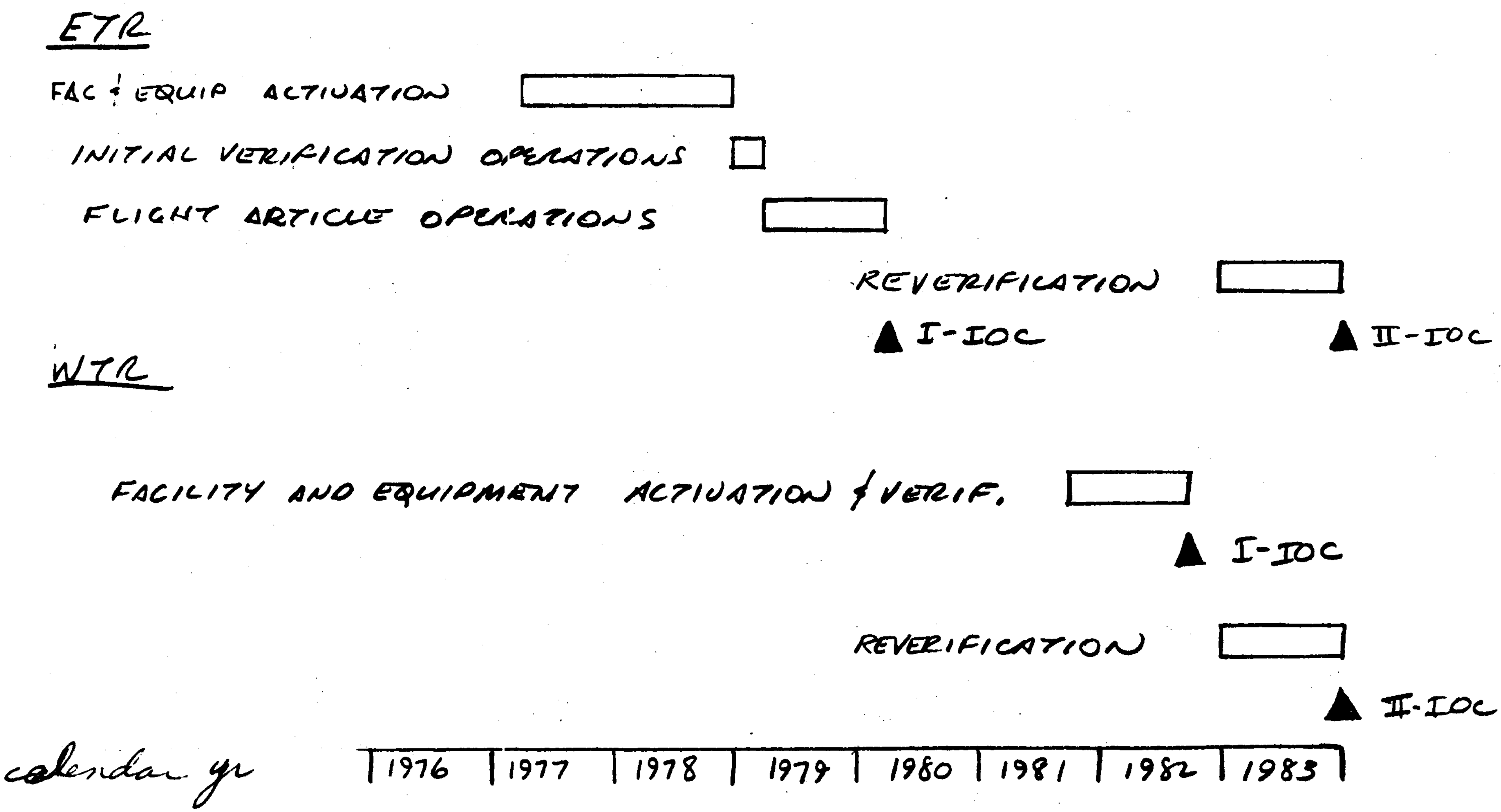
Reverification of ETR for the final configuration will be completed during a twelve month period leading up to the final phase IOC date. These activities will utilize the flight articles and the existing ground crew at ETR. This approach is possible because of the minimum vehicle (and related ground) configuration differences between the initial and final program flight articles.

Western Test Range

The activation of WTR will begin 12 months prior to the WTR initial configuration IOC date. Personnel transferred from ETR will activate the facilities and verify the ground configuration utilizing a flight vehicle. These same personnel will review, revise, and finalize the plans and procedures for the operational phase of WTR operations. Much of the equipment utilized at WTR will be provided from the factory and ground test equipment inventory.

Reverification of WTR for the final configuration will parallel the ETR activation and verification operations. The WTR activities will utilize a flight vehicle and they will depend heavily on close coordination between ETR and WTR.

Figure I
Activation and Verification Schedule
Option 3



Flight Tests

The first produced Tug will be equipped with special flight test instrumentation in support of the following objectives:

a. Propellant settling.

b. Propellant utilization.

c. Propellant feedline and engine thermal conditioning.

d. Propellant conditioning.

e. Zero-g heat transfer.

f. Avionics cold plate temperature stabilization.

g. Vibration levels of selected critical installations.

Information will be obtained from this instrumentation during the first two flights flown by this Tug. The flights will carry spacecraft for orbital placement in the event NASA is the procuring agency. These flights are dedicated test flights, however, for a DOD procured program.

Disposition of Flight Test Vehicle

Following termination of the second flight (NASA program) the flight test instrumentation will be removed and the Tug processed through a normal turn-around cycle. This Tug will then continue normal operations within the fleet. In a DOD program, data from the flight tests are a part of the total data considered by the DSARC. During this review, this Tug will continue to fly, carrying spacecraft for orbital placement, until such time as inclusion in the fleet is ordered. At this time, the instrumentation will be removed and the Tug processed through a normal turnaround cycle.

Supporting Timelines

Figure 11-1 and Figure 11-2 are the schedule for this flight test operation for Options 3I and 3F. Figure 11-3 depicts instrumentation removal time requirements and turnaround cycle time lines can be found in Section 11.3.6.

FLIGHT TEST OPERATIONS

SCHEDULE

(MONTHS)

(PHASED INITIAL AND DIRECT DEVELOPED)

O | OPT 3I I

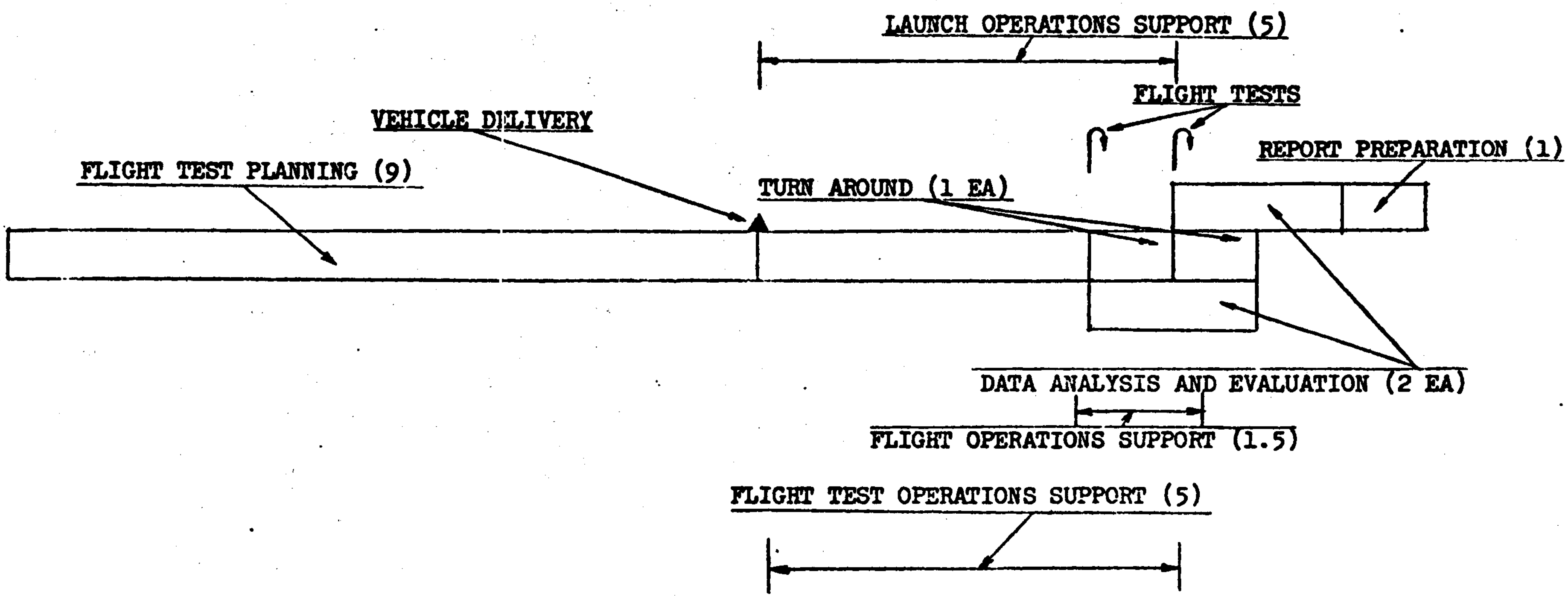


Figure 11-1

FLIGHT TEST OPERATIONS

SCHEDULE

(MONTHS)

(PHASED FINAL)

OPT 3F

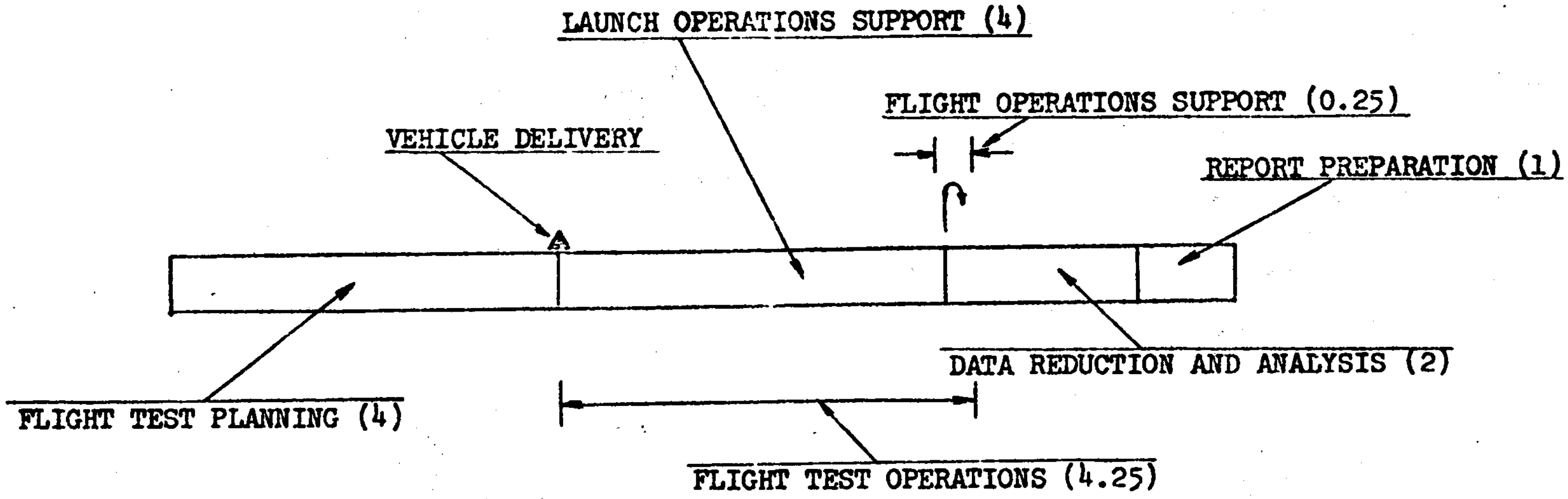


Figure 11-2

Program Options 1, 3I & 3F

Disconnect Flight Test Instrumentation

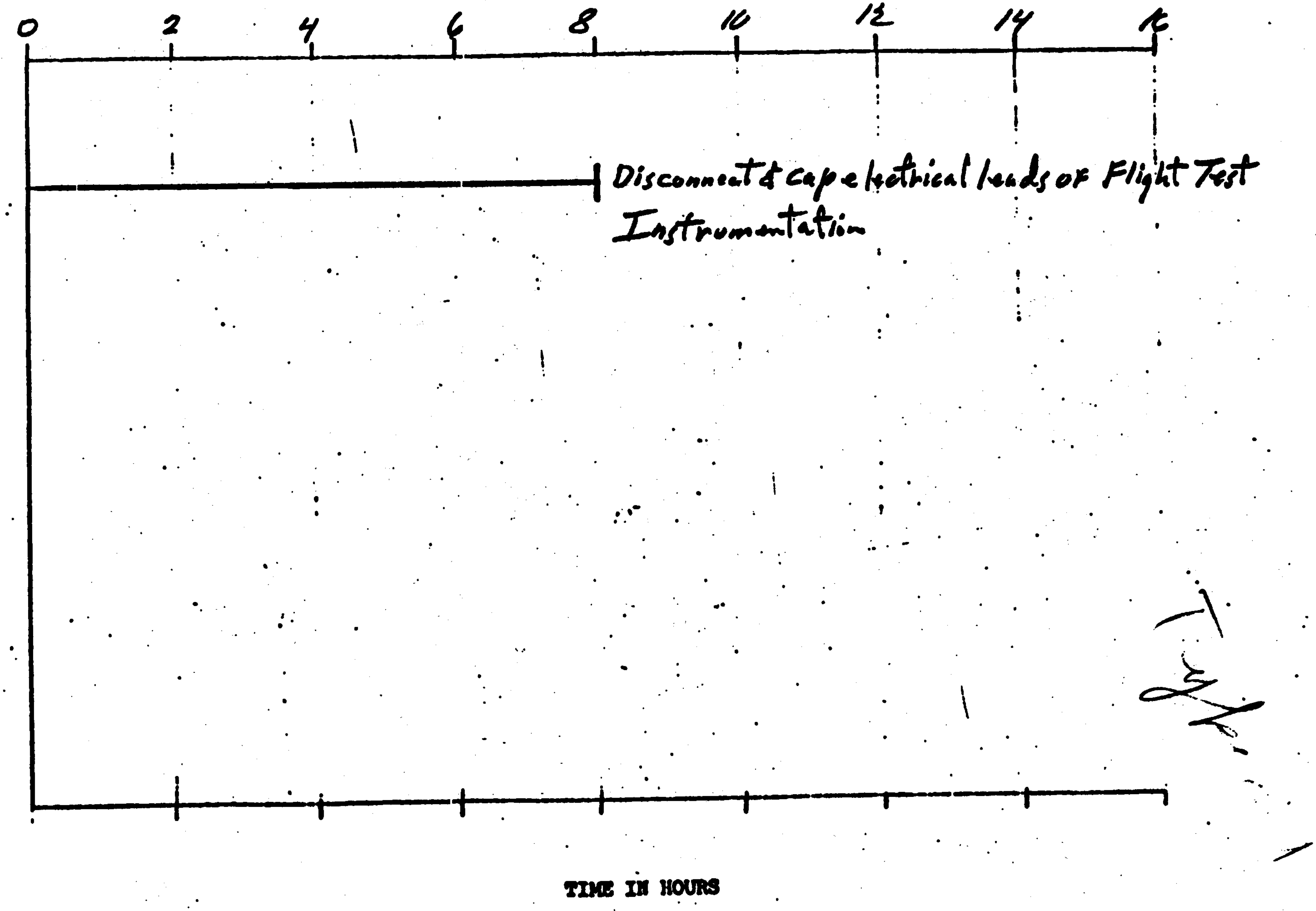


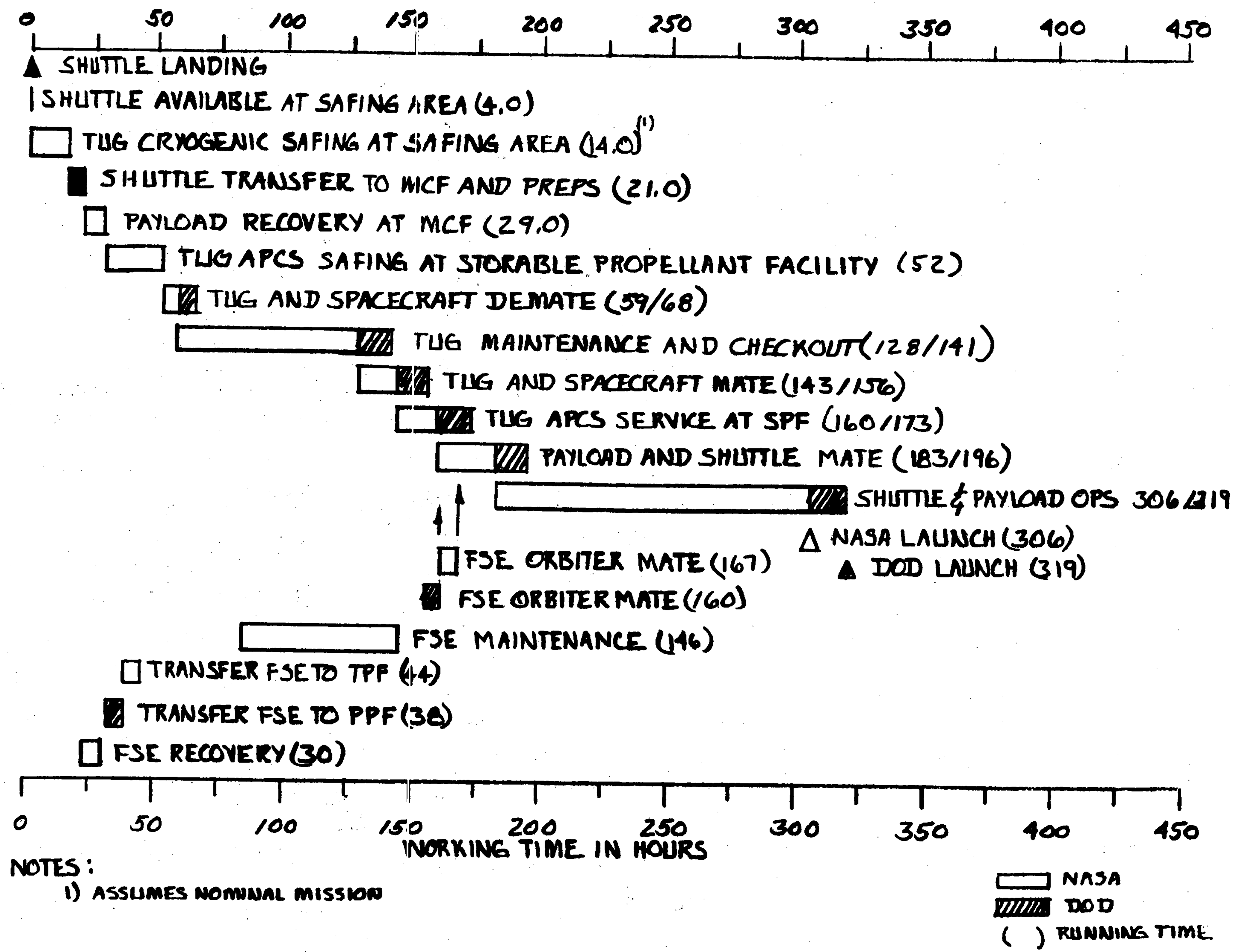
Figure 11-3 ~~3~~ 11-3

11.3.3 Top Level Functional Flows

Top level functional flows for ETR and WTR, options 3I and 3F, are presented in the form of summary time lines in Figures 11.3.3-1 through 11.3.3-4. The supporting flow diagrams are presented in Figure 11.3.3-5 through 11.3.3-8.

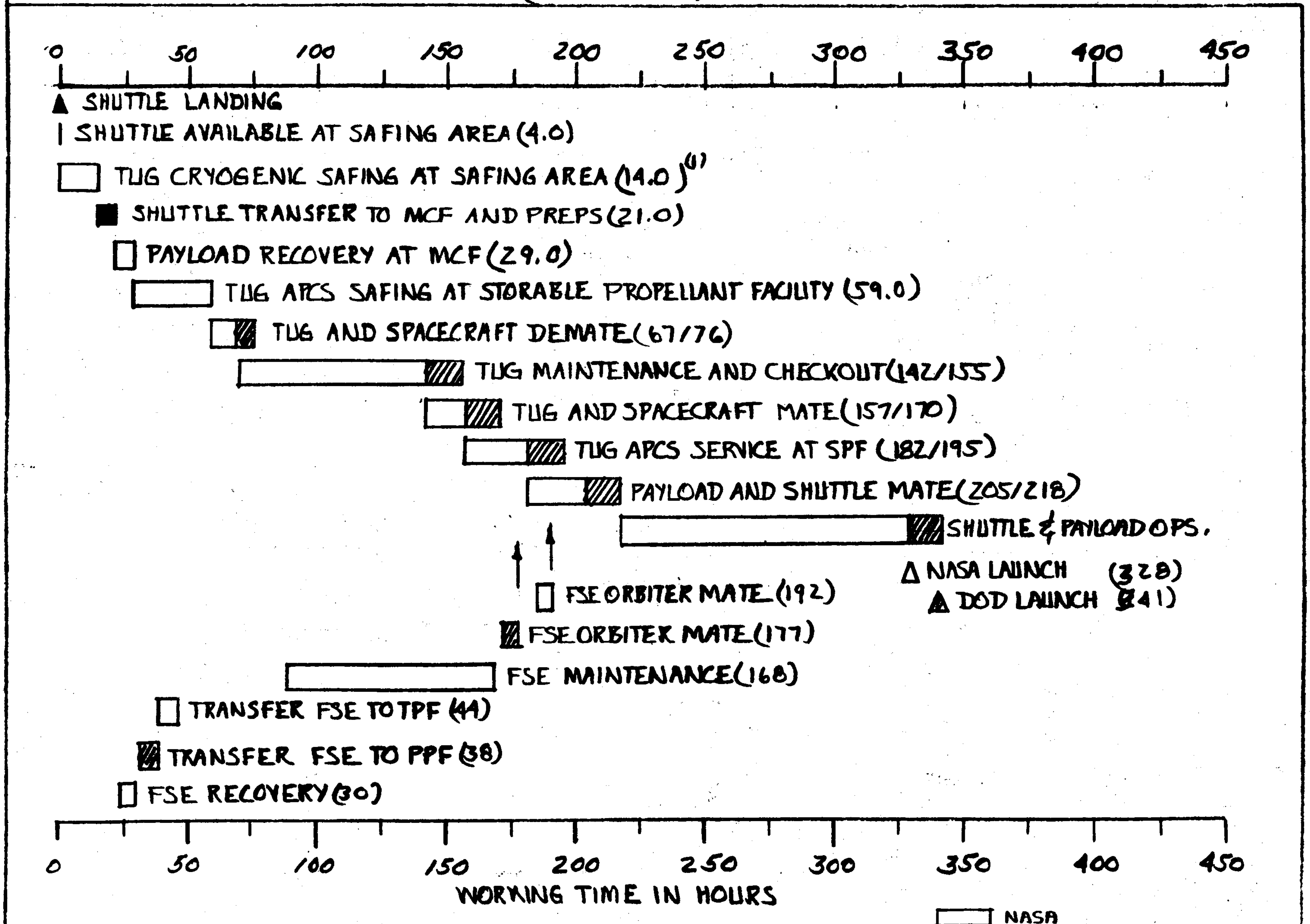
ETR TUG TURNAROUND FLOW / OPTION NO. 3 I (ROUND TR

FIG 3.2-1



NOTES:
1) ASSUMES NOMINAL MISSION

ETR TUG TURNAROUND FLOW/ OPTION NO. 3F (ROUND TRIP) FIG 11.3.3-2

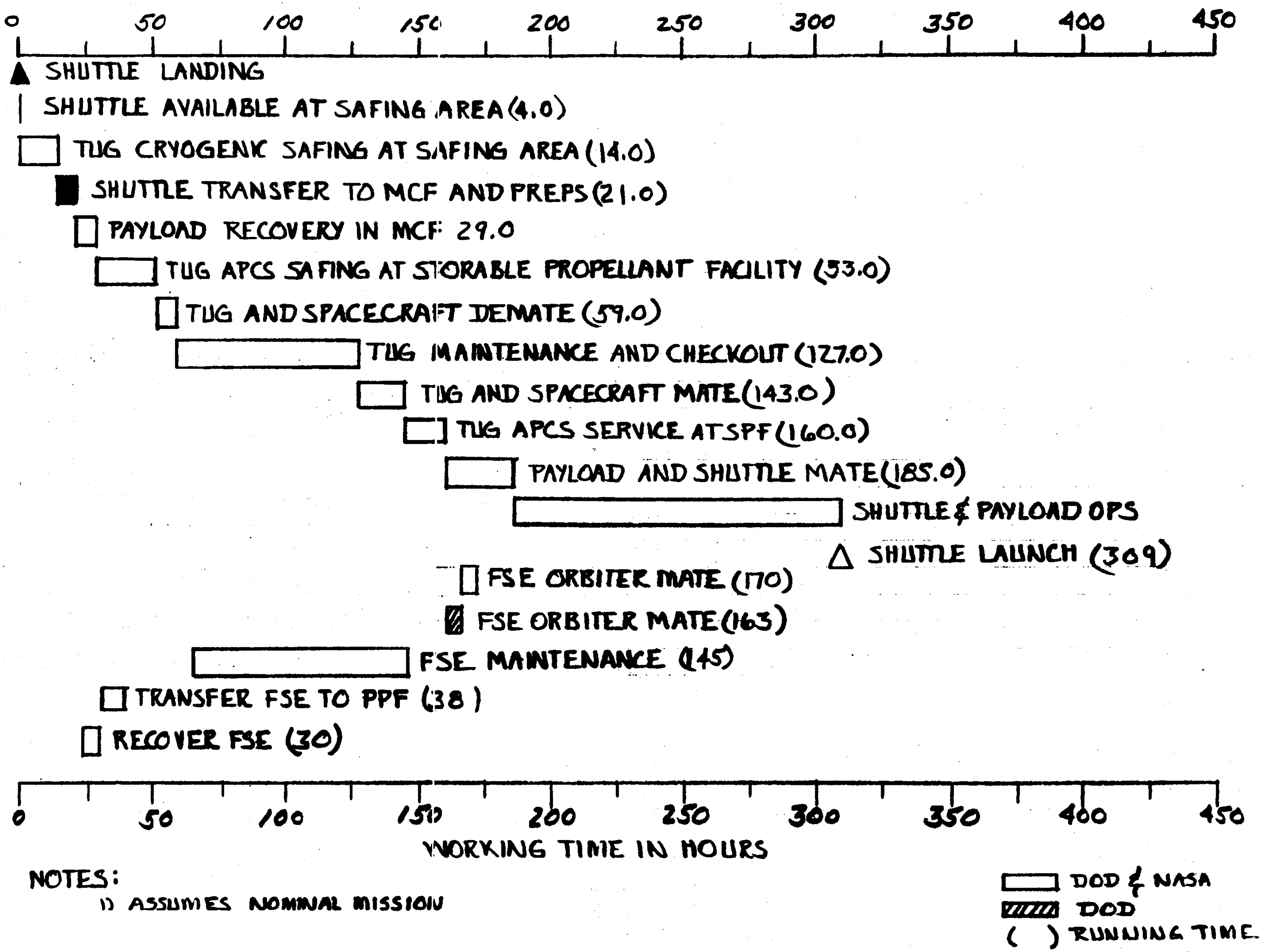


NOTE:
1) ASSUMES NOMINAL MISSION

WTR TUG TURNAROUND FLOW / OPTION NO. 3 I

ROUN[illegible]

FIG [illegible]3.3-3

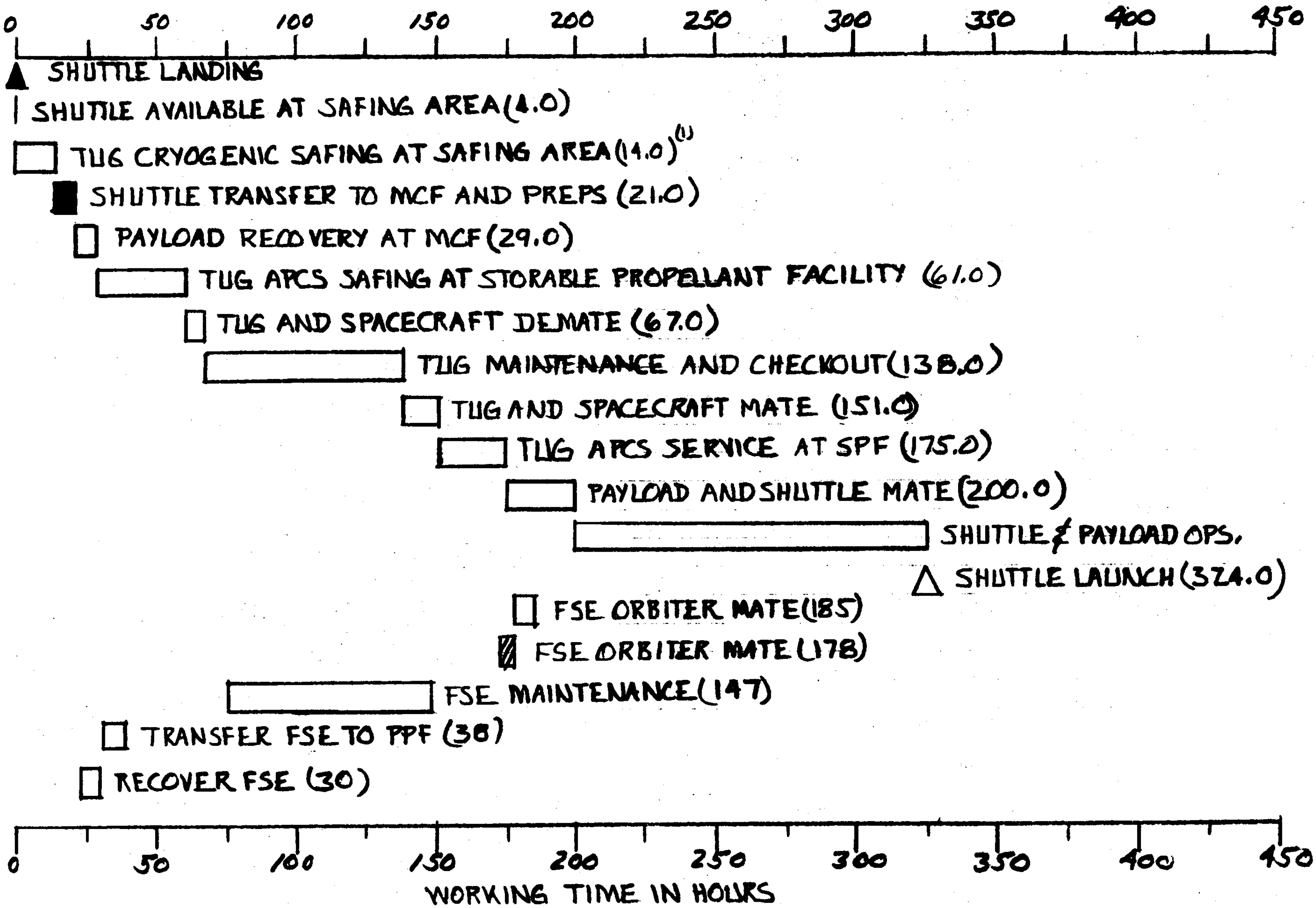


NOTES:

1) ASSUMES NOMINAL MISSION

WTR TUG TURNAROUND FLOW/OPTION NO. 3F (ROUND TRIP)

FIG 11.3.3-4



NOTES:
1) ASSUMES NOMINAL MISSION

ALL OPTIONS

WTR/KSC 1.0 - NOMINAL TUG MAINTENANCE AND REFURBISHMENT FLOW

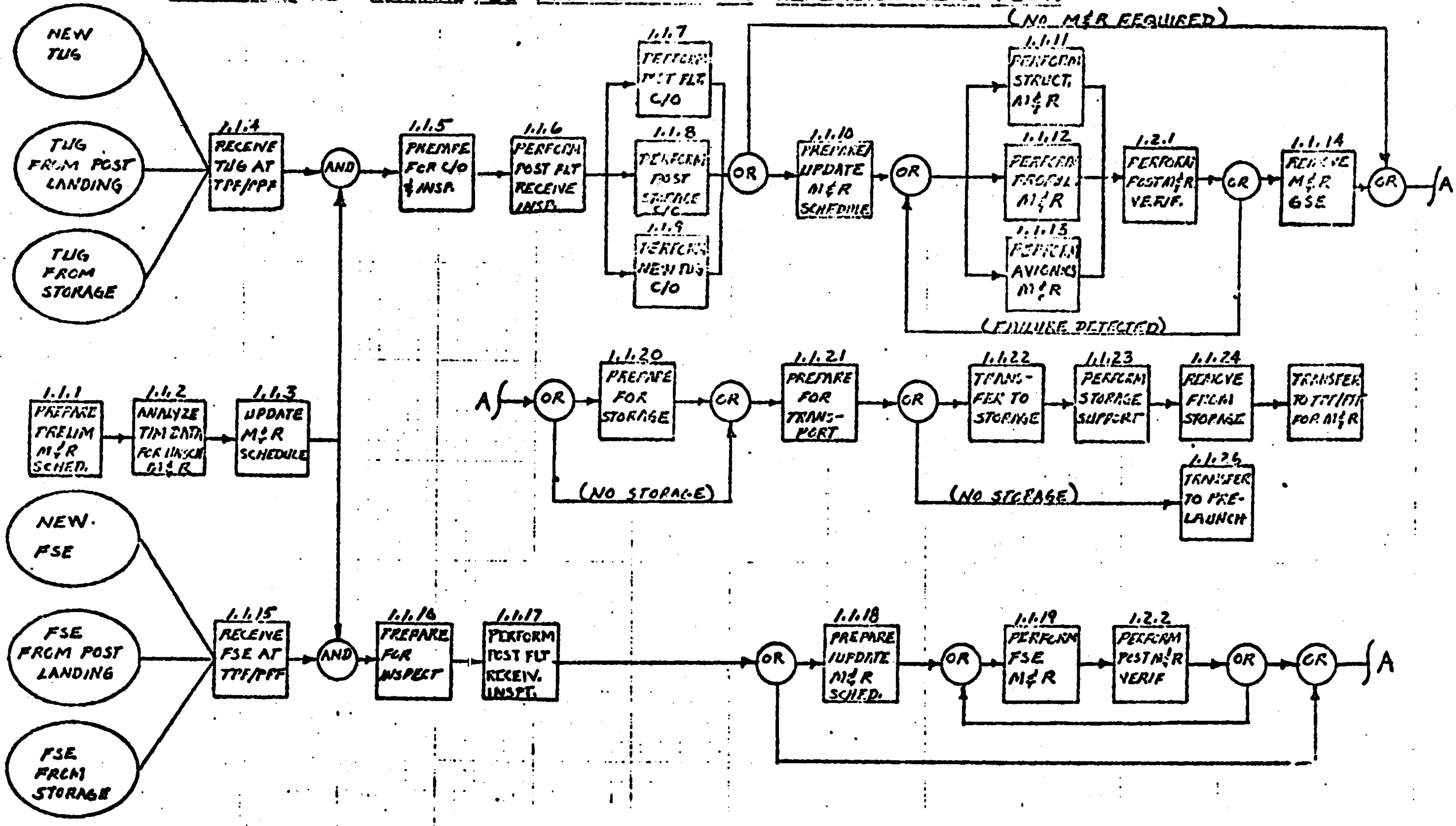


FIG 11.3.3-5

WTR 2.0 PRELAUNCH AND LAUNCH CHECKOUT FLOW

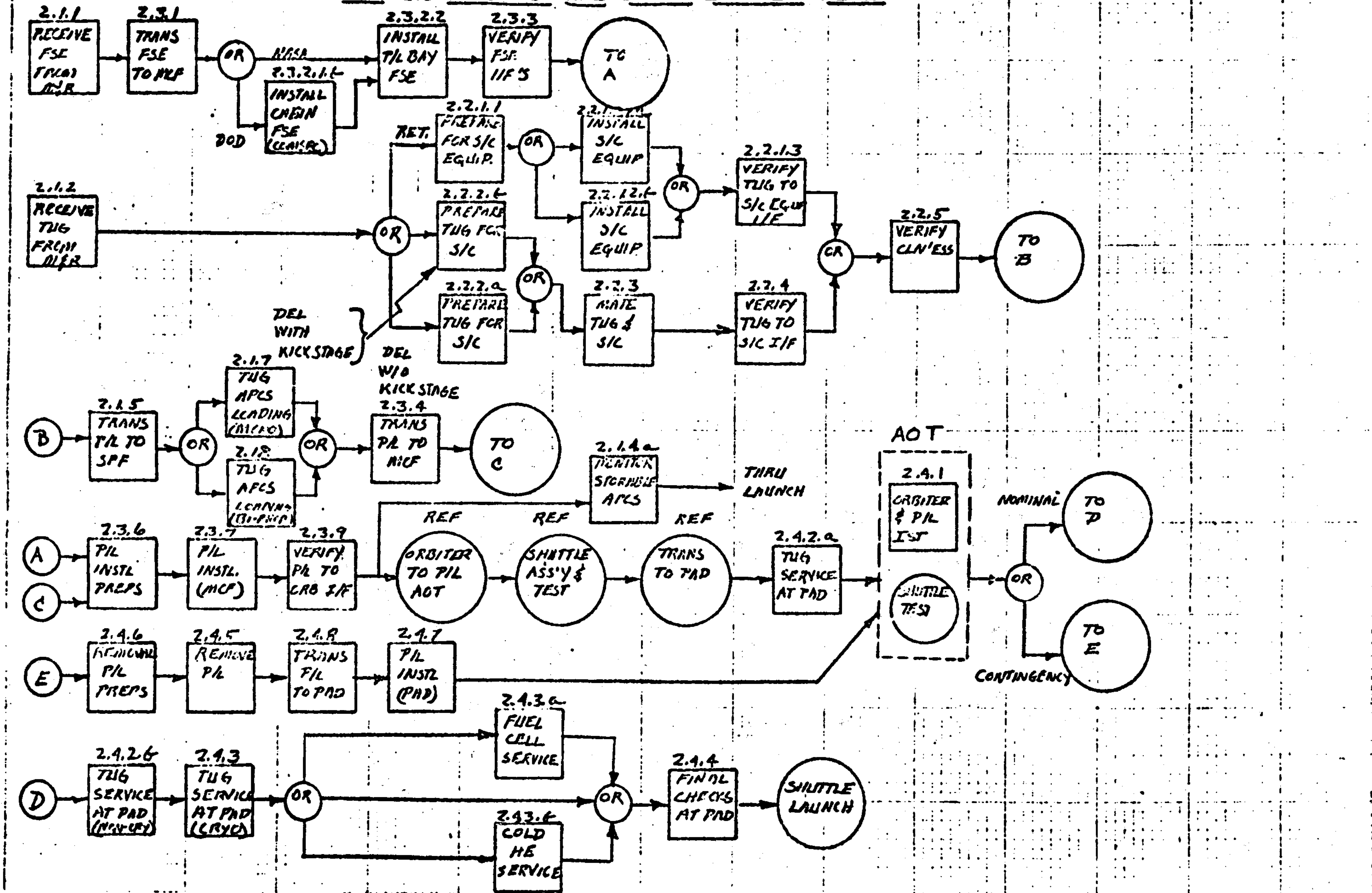


FIG 11.3.2-5 (CONT.)

WTR 3.0 POST-LANDING OPERATIONS FLOW

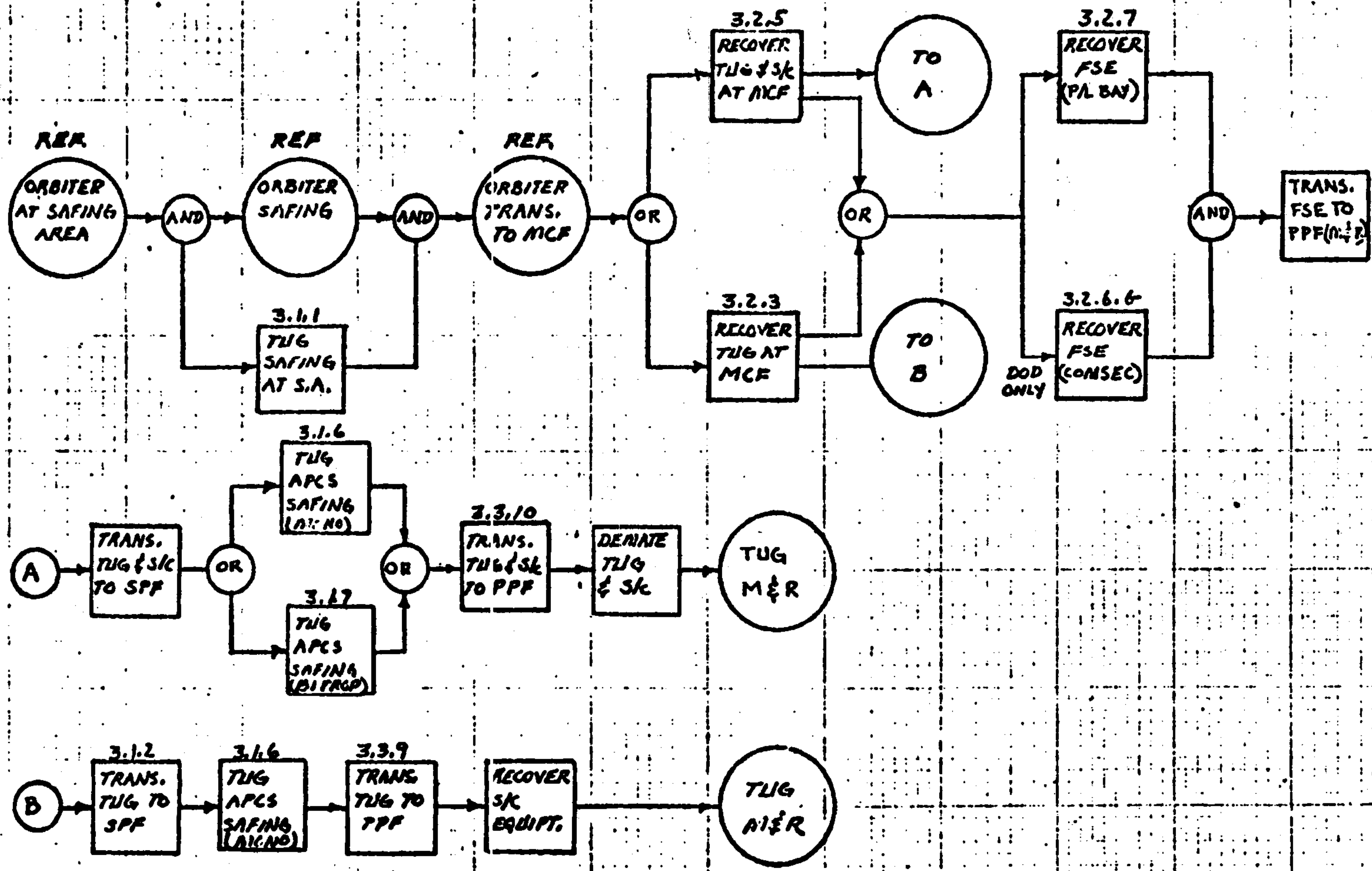


FIG 11.3.3-5 (CONT.)

ALL OPTIONS

WTR/KSC 1.0 - NOMINAL TUG MAINTENANCE AND REFURBISHMENT FLOW

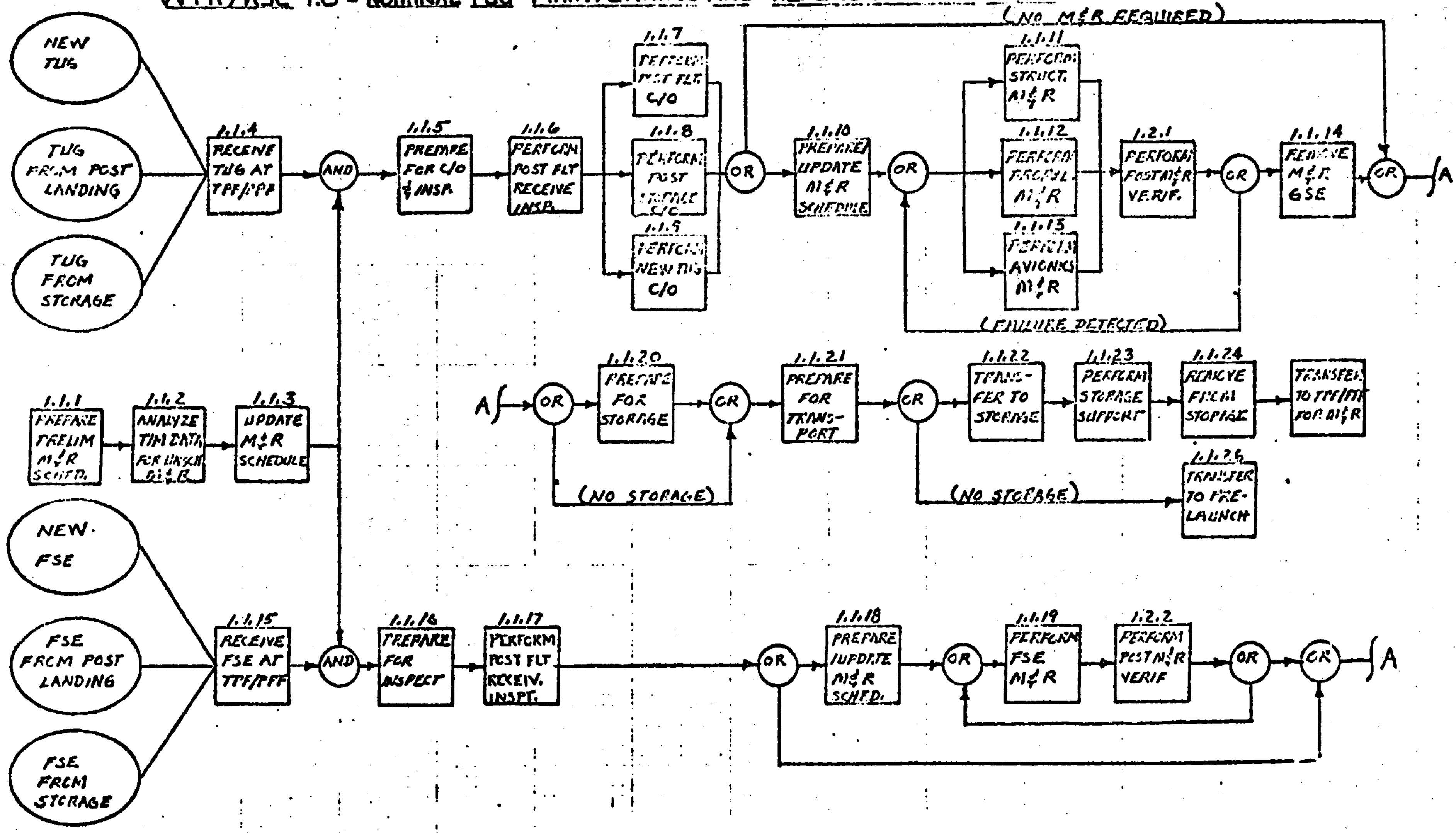


FIG 11.3.3-6

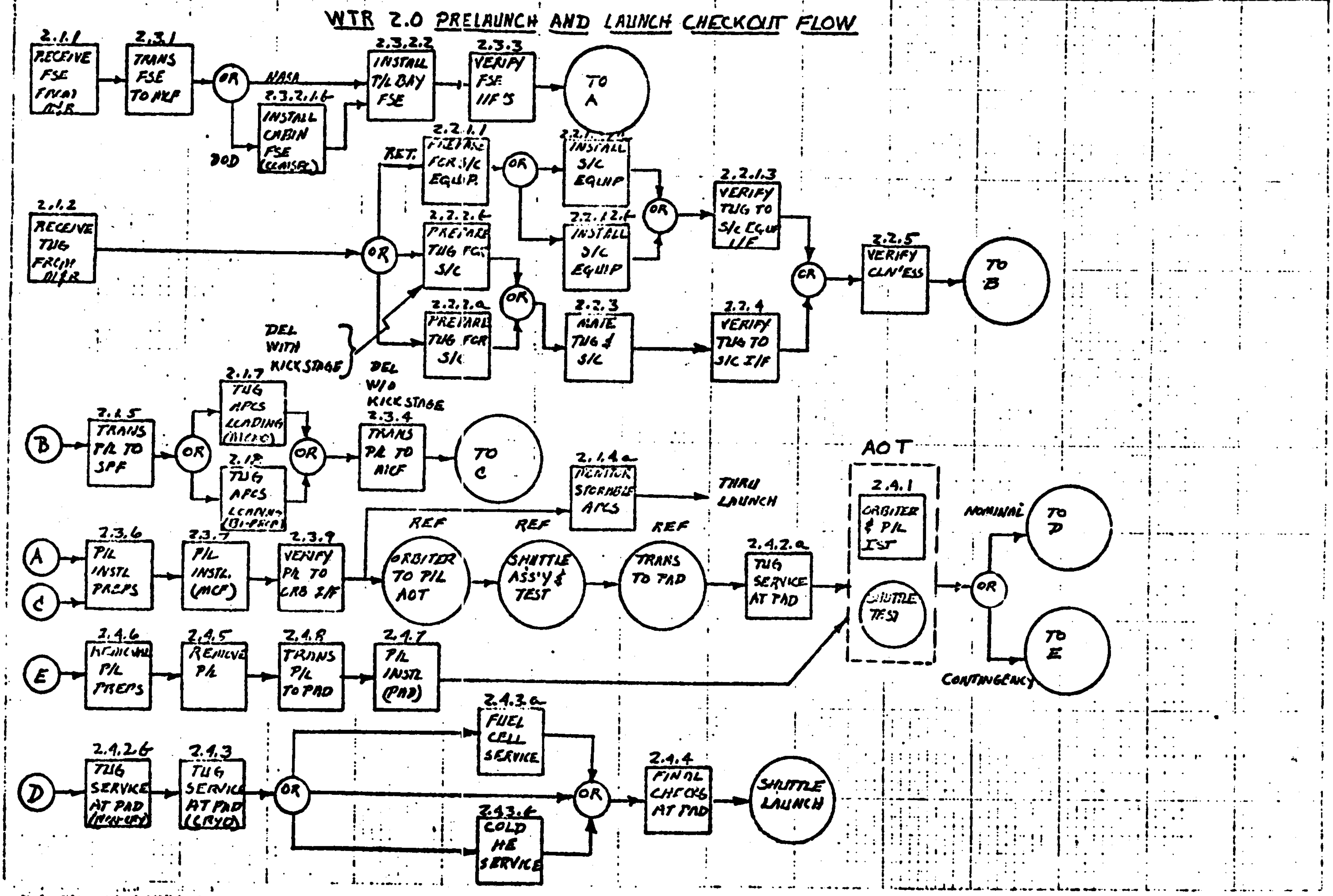
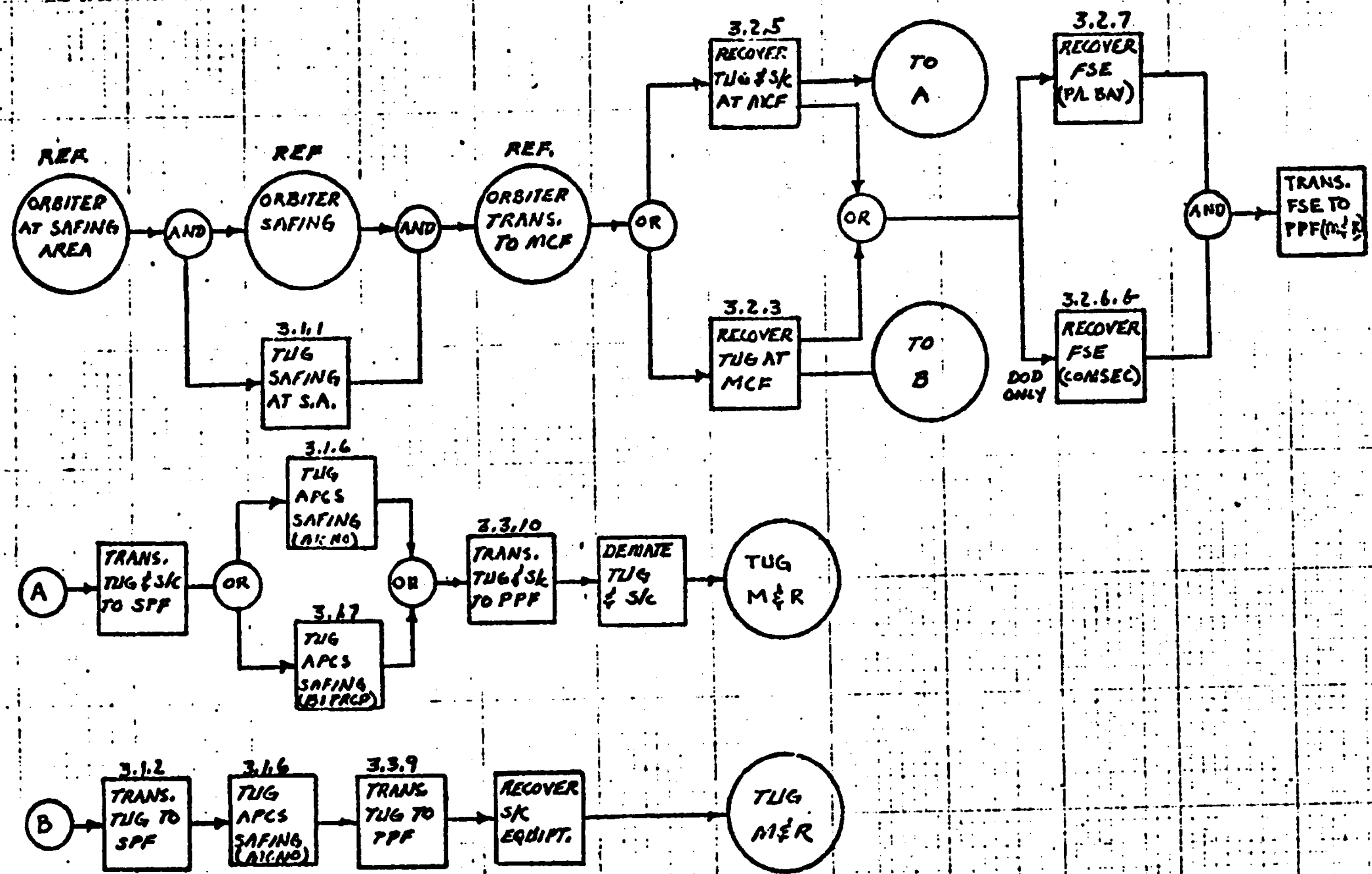


FIG. 11.3.3 -6 (CONT.)

WTR 3.0 POST-LANDING OPERATIONS FLOW



FIG( ).3.3-6 (CONT.)

ALL OPTIONS

WTR/KSC 1.0 - NOMINAL TUG MAINTENANCE AND REFURBISHMENT FLOW

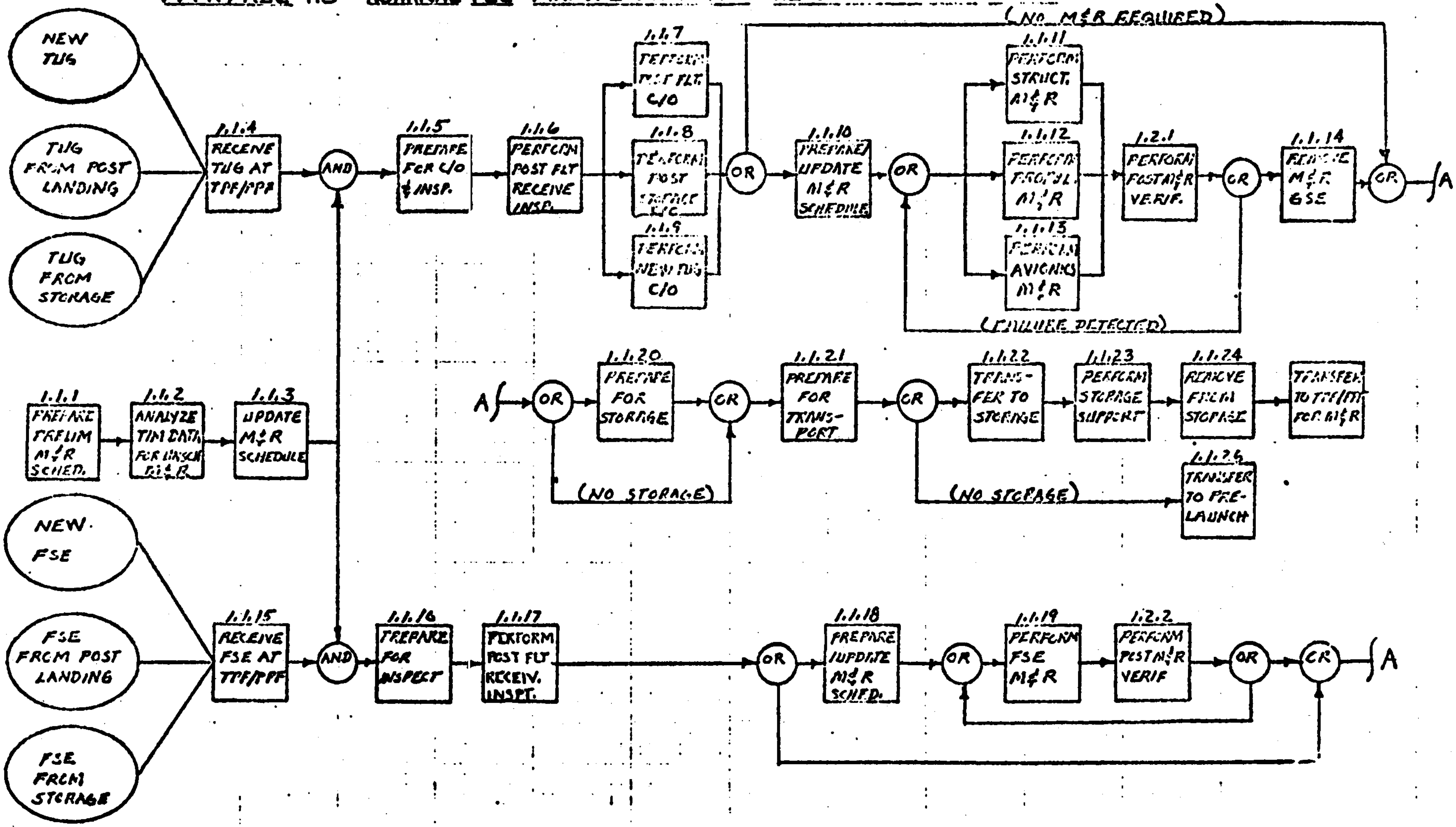


FIG 11.3.3-7

KSC 2.0 PRELAUNCH AND LAUNCH CHECKOUT FLOW

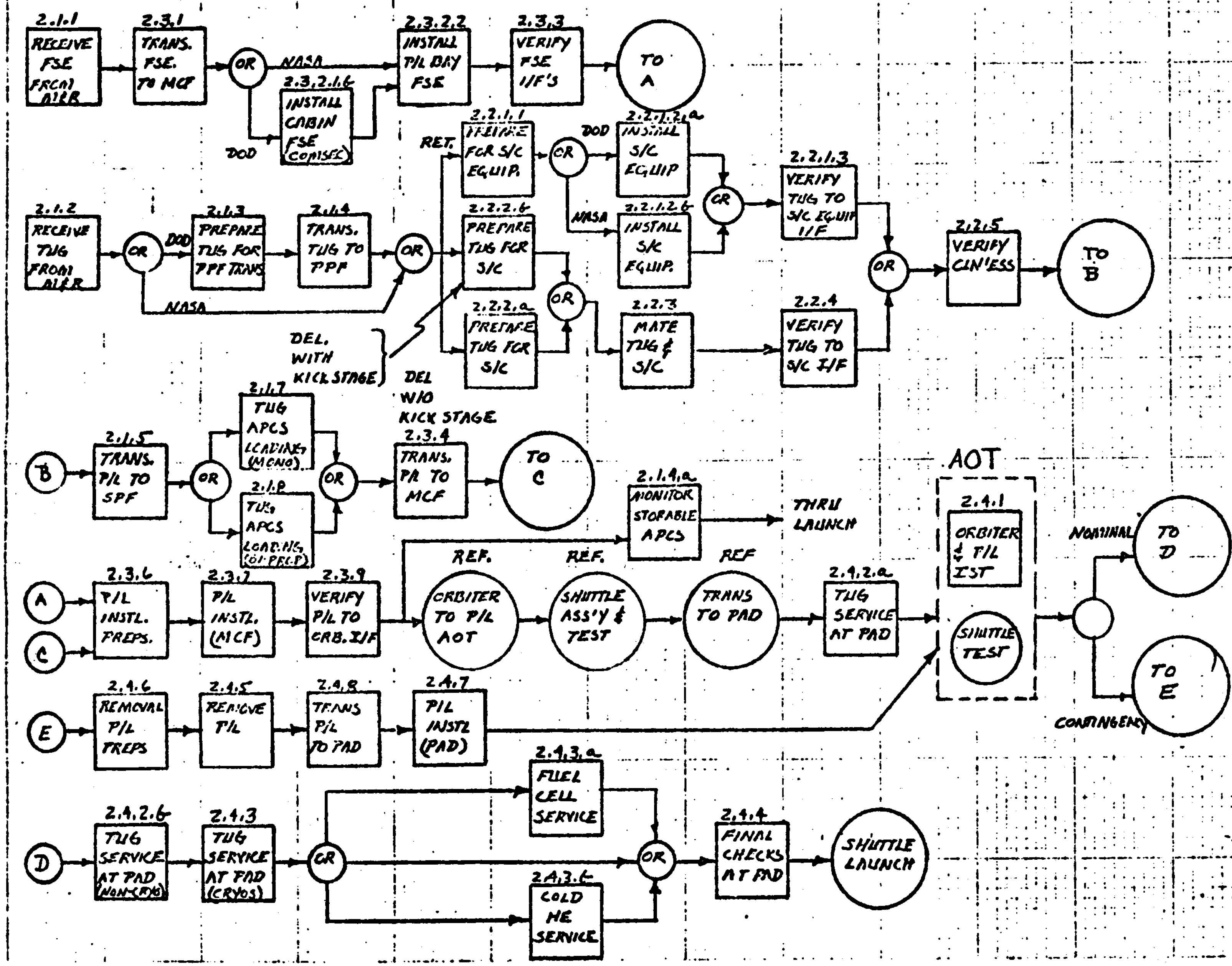


FIG. 11.3 [illegible]-7 (CONT.)

KSC 3.0 POST-LANDING OPERATIONS FLOW

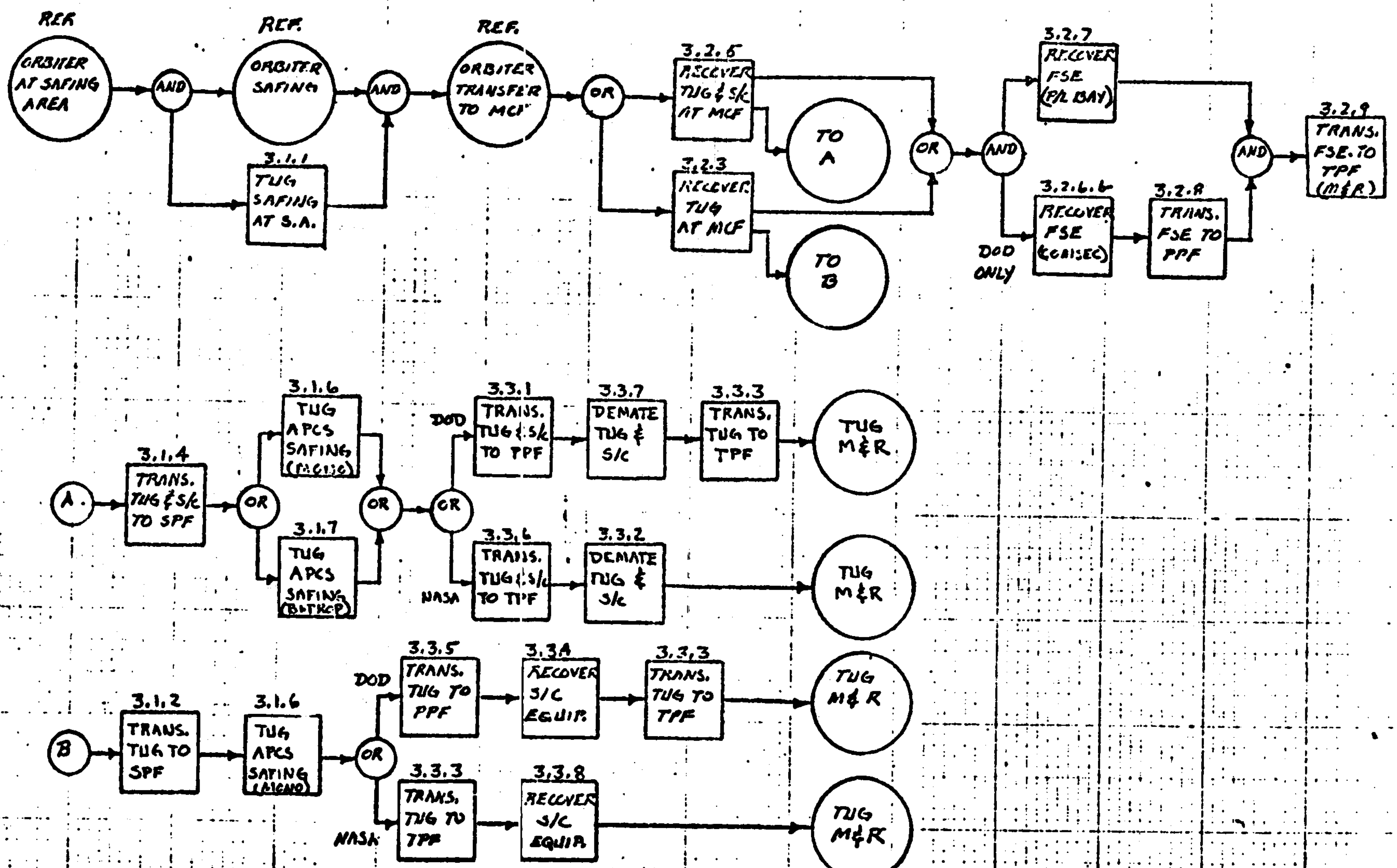


FIG. 11.3.3-7 (CONT.)

ALL OPTIONS

WTR/KSC 1.0 - NOMINAL TUG MAINTENANCE AND REFURBISHMENT FLOW

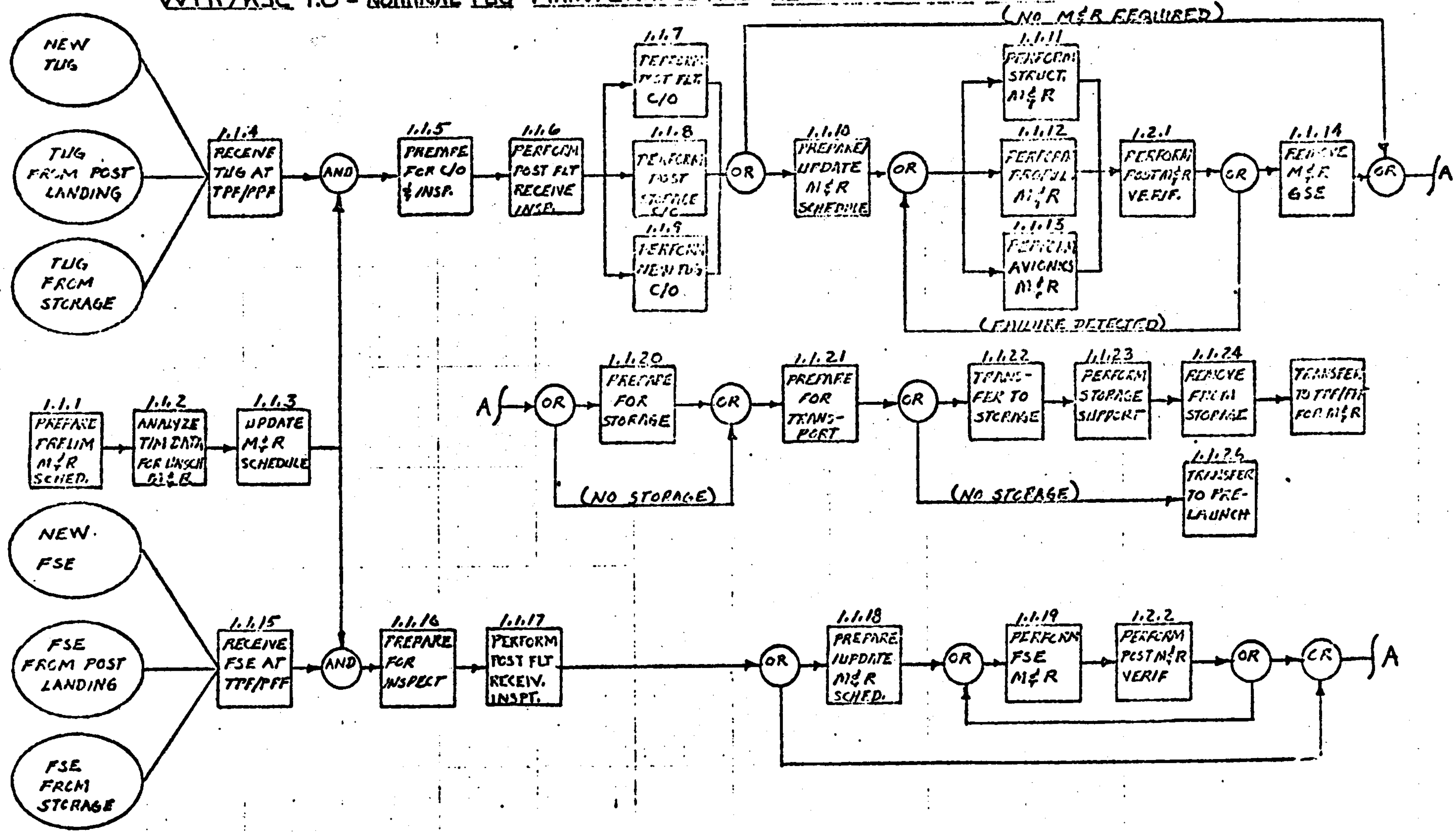


FIG 11.3.3-8

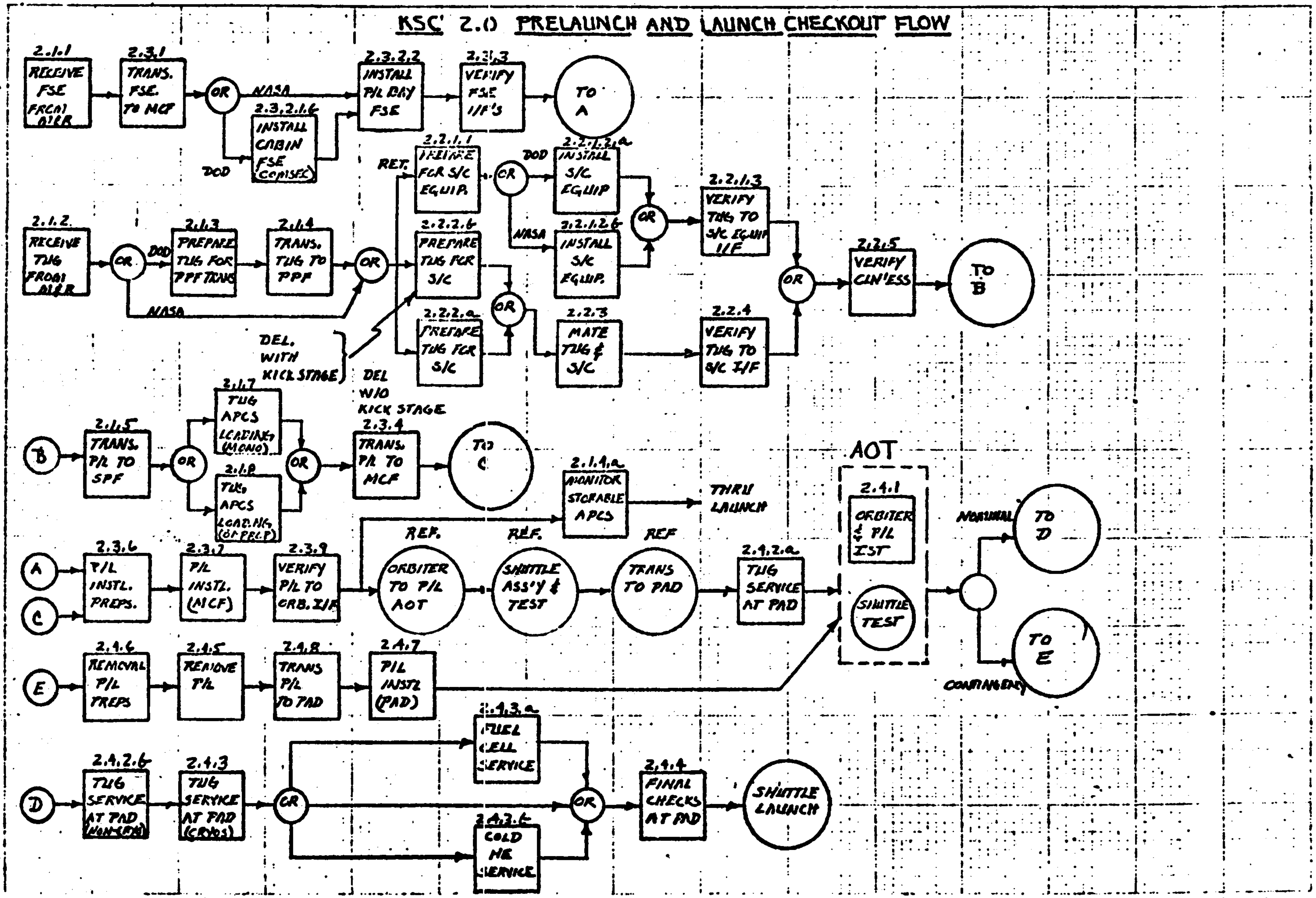
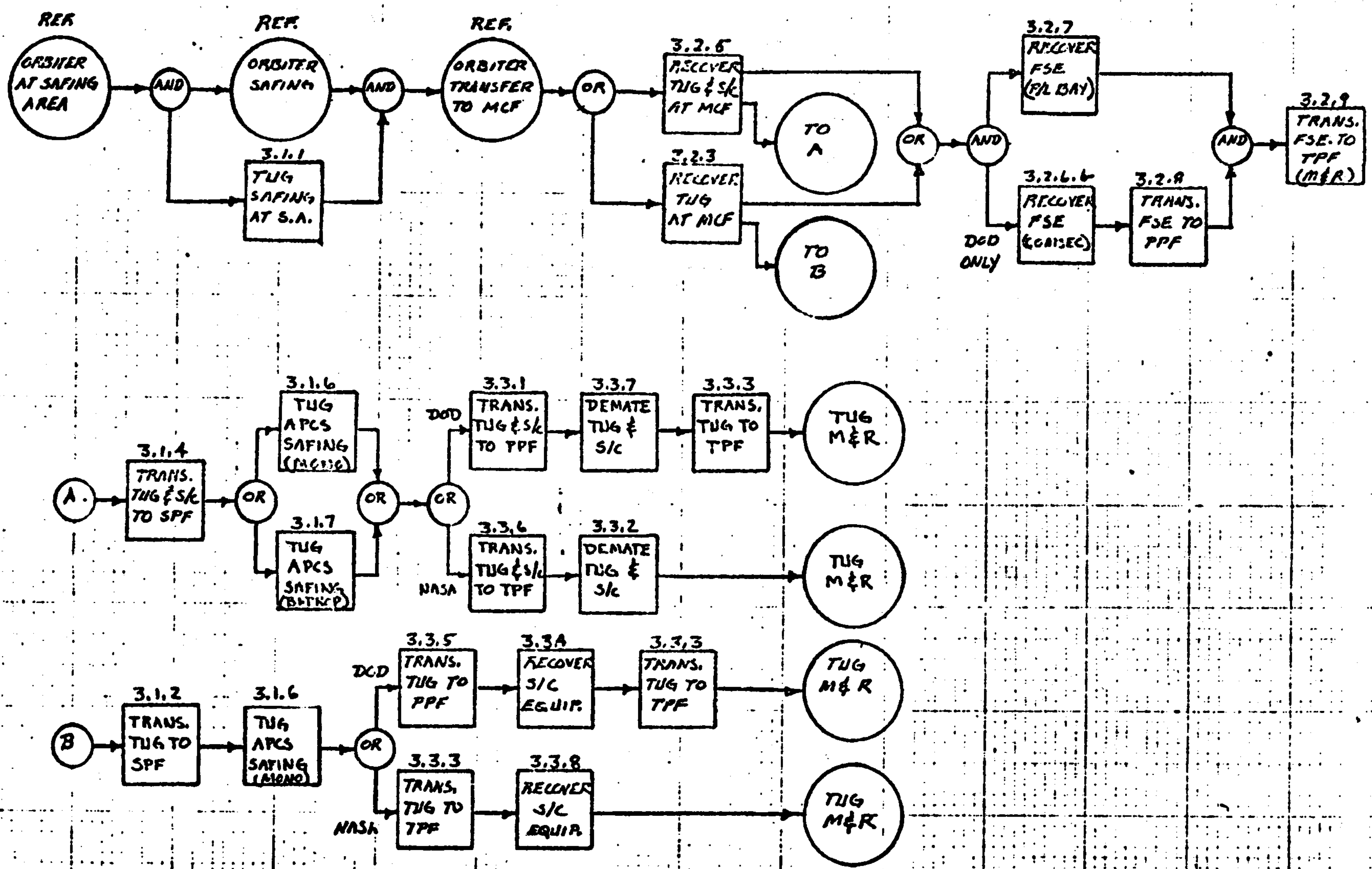


FIG 11.3.3-B (CONT.')

KSC 3.0 POST-LANDING OPERATIONS FLOW



FI 11.3.3-8 (CONT.')

11.3.4 Tug Operations Sensitivities to Tug Configurations

Each T[illegible] option configuration was assessed with respect to

A. Turnaround time

B. Manpower

C. GSE

D. Depot maintenance

E. Facilities

for the following Tug configuration differences

A. Retrieval vs. no-retrieval

B. Mono-propellant vs bi-propellant

C. Cold helium vs ambient helium pressurization

D. Fuel cells vs batteries

E. NASA security vs DOD security

F. Kick stage vs no kick stage

G. Engine configuration

H. On-orbit time

I. Autonomy level

J. Abort requirements

Results of these sensitivity analyses are summarized as follows:

Turnaround Time

The key drivers in Tug ground turnaround time sensitivity to Tug configurations are:

A. Retrieval vs no retrieval

B. Monopropellant vs bi-propellant

C. Kick stage vs no kick stage

Retrieval, bipropellant, and kick stage ground operations increase ground turnaround by 5 hours, 15 hours, and 1 hour respectively.

Manpower

The configurations which influence manpower are as follows:

A. Cold helium pressurization operations increase the mandatory required manpower by four people

B. Fuel cell operations increase mandatory required manpower by six people.

C. DOD security requirements increase the maximum required manpower by two people.

D. Kick stage operations increase the maximum required manpower by six people.

GSE

The key drivers in GSE sensitivity to Tug configurations are as follows:

A. Retrieval operations requires spacecraft/Tug demating GSE at the PPF and TPF.

B. Bi-propellants require bi-propellant handling and storage GSE at the storable propellant facility.

C. Cold helium operations adds maintenance and refurbishment GSE at the MCF and servicing GSE at the launch pad.

D. Fuel cell operations add maintenance and refurbishment GSE at the MCF and servicing GSE at the launch pad.

E. DOD security requires COMSEC checkout GSE at the PPF and an inter-facility security transport vehicle for Tugs which fly classified payloads.

F. Kick stage operations add additional kick stage/Tug integration GSE at the PPF or TPF.

Depot Maintenance

The configurations which influence depot maintenance are:

A. Monopropellant APCS requires the replacement of 12 sets of aft firing thrusters.

B. Category 2A RL-10 engine requires 12 engine overhauls.
Category I RL-10 engine requires 18 engine overhauls.

Facilities

Facilities are relatively insensitive to Tug configurations with exception to kick stage missions which require an ordnance facility for kick stage storage and assembly.

Tug Configuration / Option Sensitivity	Option 1 Turnaround Time	Option 2 Turnaround Time	Option 3I Turnaround Time	Option 3F Turnaround Time	Option 3 Turnaround Time
Retrieval/No Retrieval	Retrieve capability increases turnaround 5 hrs	No retrieval capability reduces turnaround 5 hrs	Same as Option 2	Same as Option 2	Same as Option 2
Monopropellant/ Bi-propellant	Bi-propellant increases turnaround 15 hours	Monopropellant decreases turnaround 15 hrs	Bi-propellant increases turnaround 15 hrs	Monopropellant decreases turnaround 15 hrs	Monopropellant reduces 15 hrs Bipropellant increases 15 hrs.
Cold Helium/ Ambient Helium Pressurization	Cold helium has no effect	Cold helium has no effect	Cold helium has no effect	Ambient helium has no effect	No effect
Fuel Cells/ Batteries	Fuel cells have no effect	Batteries have no effect	Fuel cells have no effect	Batteries have no effect	No effect
NASA/DOD Security	DOD security adds 7 hrs to turnaround	Same as Option 1	Same as option 1	Same as Option 1	Same as Option 1
Kick Stage/No Kick Stage	Kick stage adds 1 hr to turnaround	Same as Option 1	Same as Option 1	Same as Option 1	Same as Option 1
Engine Configuration	Cat 2A RL-10 has no effect	Cat 1 RL-10 has no effect	Cat 2A RL-10 has no effect	Cat 2A RL-10 has no effect	Cat 2A RL-10 has no effect
On-Orbit Time	No effect on ground ops	Same as Option 1	Same as Option 1	Same as Option 1	Same as Option 1
Autonomy Level	Autonomy Level III has no effect	Autonomy Level IV has no effect	Same as Option 1	Same as Option 2	No effect
Abort Req'mts	No effect	No effect	No effect	No effect	No effect

Option Sensitivity / Tug Configuration	Option 1 Manpower	Option 2 Manpower	Option 3I Manpower	Option 3F Manpower	Option 3 Manpower
Retrieval/No Retrieval	Retrieval has no effect on manpower req'mts	No retrieval has no effect on manpower req'mts	Same as Option 2	Same as Option 2	No effect
Monopropellant/ Bi-propellant	Bi-propellant has no effect on maximum manpower req'd	Monopropellant has no effect on maximjm manpower req'd	Same as Option 1	Same as Option 2	No effect
Cold Helium/ Ambient Helium Pressurization	Cold Helium increases mandatory manpower by 4	Same as Option 1	Same as Option 1	Ambient helium reduces mandatory manpower by 4	Ambient helium reduces mandatory manpower by 4
Fuel Cells/ Batteries	Fuel cells increase mandatory manpower by 6	Batteries reduce mandatory manpower by 6	Same as Option 1	Same as Option 2	Fuel cells increase mandatory req'mt by 6. Batteries reduce mandatory req'mt by 6
NASA/DOD Security	DOD security increases max. manpower req'mt by 2	Same as Option 1	Same as Option 1	Same as Option 1	DOD security increases max. manpower req'mt by 2
Kick Stage/ No Kick Stage	Kick Stage increases max. manpower reqm't by 6	Same as Option 1	Same as Option 1	Same as Option 1	Kick Stage increases max. manpower req'mt by 6
Engine Configuration	Cat 2A RL-10 has no effect	Cat 1 RL-10 has no effect	Same as Option 1	Same as Option 1	No effect
On-Orbit Time	6 day on-orbit time has no effect	36 hour on-orbit time has no effect	6 day on-orbit time has no effect	36 hour on-orbit time has no effect	No effect
Autonomy Level	Autonomy Level III has no effect	Autonomy Level IV has no effect	Same as Option 1	Same as Option 2	No effect
Abort Req'mts	No effect on manpower req'mts	Same as Option 1	[illegible]e as Option 1	Same as Option 1	No effect on man-[illegible]

Option Sensitivity / Tug Configuration	Option 1	Option 2	Option 3I	Option 3F	Option 3
	GSE	GSE	GSE	GSE	GSE
Retrieval/No Retrieval	Retrieval requires S/C demate GSE at PPF and TPF	No retrieval eliminates S/C demate GSE at PPF and TPF	Same as Option 2	Same as Option 2	No retrieval eliminates S/C demate GSE at PPF and TPF
Monopropellant/ Bi-propellant	Bi-propellant requires B-prop handling and storage GSE at SPF	Monopropellant eliminates bi-prop handling and storage GSE at SPF	Same as Option 1	Same as Option 2	Same as Options 3I and 3F
Cold Helium/ Ambient Helium Pressurization	Cold helium adds M&R and servicing GSE at TPF and launch pad	Same as Option 1	Same as Option 1	Ambient helium eliminates M&R and servicing GSE for cold helium at TPF and launch pad	Same as Options 3I and 3F
Fuel Cells/ Batteries	Fuel cells and M&R and servicing GSE at TPF and launch pad	Batteries eliminate fuel cell M&R and servicing GSE at TPF and launch pad	Same as Option 1	Same as Option 2	Same as Options 3I and 3F
NASA/DOD Security	DOD security requires COMSEC checkout GSE and inter-facility security transport vehicle	Same as Option 1	Same as Option 1	Same as Option 1	Same as Option 1
Kick Stage/ No Kick Stage	Kick Stage requires additional Tug/Kick-stage integration GSE	Same as Option 1	Same as Option 1	Same as Option 1	Same as Option 1
Engine Configuration	Cat 2A RL-10 has no effect	Cat 1 RL-10 has no effect	Same as Option 1	Same as Option 1	Same as Option 1

Option Sensitivity / Tug Configuration	Option 1	Option 2	Option 3I	Option 3F	Option 3
	GSE	GSE	GSE	GSE	GSE
On-Orbit Time	No effect	No effect	No effect	No effect	No effect
Autonomy Level	Level III has no effect	Level IV has no effect	Same as Option 1	Same as Option 1	No effect
Abort Req'mts	No effect	No effect	No effect	No effect	No effect

Option Sensitivity / Tug Configuration	Option 1 Depot Maintenance	Option 2 Depot Maintenance	Option 3I Depot Maintenance	Option 3F Depot Maintenance	Option 3 Depot Maintenance
Retrieval/ No Retrieval	Retrieval has no effect	No retrieval has no effect	Same as Option 2	Same as Option 2	No effect
Monopropellant/ Bi-propellant	Bi-propellant requires no depot maintenance	Monopropellant requires replacement of 12 aft firing thruster sets	Bi-propellant requires no depot maintenance	Bi-propellant requires replacement of 12 aft firing thruster sets	Same as Option 3I and 3F
Cold Helium/ Ambient Helium Pressurization	Cold helium requires no depot maintenance	Same as Option 1	Same as Option 1	Ambient helium requires no depot maintenance	Same as Options 3I and 3F
Fuel Cells/ Batteries	Fuel cells require no depot maint.	Fuel cells req'd for 6 day mission	Fuel cells require no depot maint.	Fuel cells req'd for 6 day mission	Same as Options 3I and 3F
NASA/DOD Security	No effect	No effect	No effect	No effect	No effect
Kick Stage/ No Kick Stage	No effect	No effect	No effect	No effect	No effect
Engine Configuration	Cat 2A RL-10 Requires 12 engine overhauls	Cat 1 RL-10 requires 18 engine overhauls	Same as Option 1	Same as Option 1	Same as Option 1
On-Orbit Time	No effect	No effect	No effect	No effect	No effect
Autonomy Level	No effect	No effect	No effect	No effect	No effect
Abort Req'mts	No effect	No effect	No effect	No effect	No effect

11-55

Option Sensitivity / Tug Configuration	Option 1 Facilities	Option 2 Facilities	Option 3I Facilities	Option 3F Facilities	Option 3 Facilities
Retrieval/ No Retrieval	Retrieval has no effect	No Retrieval has no effect	Same as Option 2	Same as Option 2	No effect
Monopropellant/ Bi-Propellant	Bi-propellant has no effect	Monopropellant has no effect	Same as Option 1	Same as Option 2	No effect
Cold Helium/ Ambient Helium Pressurization	Cold helium has no effect	Same as Option 1	Same as Option 1	Ambient helium has no effect	No effect
Fuel Cells/ Batteries	Fuel cells have no effect	Batteries have no effect	Same as Option 1	Same as Option 2	No effect
NASA/DOD Security	DOD security requires a PPF	DOD security requires a PPF	DOD security requires a PPF	DOD security requires a PPF	DOD security requires a PPF
Kick Stage/ No Kick Stage	Kick stage requires ordnance facility	Same as Option 1	Same as Option 1	Same as Option 1	Kick stage requires ordnance facility
Engine Configuration	Cat 2A RL-10 has no effect	Cat 1 RL-10 has no effect	Same as Option 1	Same as Option 1	No effect
On-Orbit Time	No effect	No effect	No effect	No effect	No effect
Autonomy Level	No effect	No effect	No effect	No effect	No effect
Abort Req'mts	No effect	No effect	No effect	No effect	No effect

11.3.5 Operations Constrained by the Orbiter

The Tug operations which are constrained by the Orbiter for Option 3I and 3F are listed below according to their corresponding Function Breakdown Number. These operations are time constrained in order to not interfere with the Orbiter ground turnaround schedule.

F.B.N TUG OPERATIONS CONSTRAINED BY THE ORBITER

2.3 TUG/SHUTTLE MATE

- 2.3.7 Payload Installation MCF
- 2.3.9 Verify Payload-To-Shuttle Interfaces

2.4 COUNTDOWN

- 2.4.1 Orbiter/Payload Integrated System Test
- 2.4.1a Monitor Storable ACPS
- 2.4.2a Tug Service at Pad
- 2.4.2b Tug Service at Pad (Non-Cryo)
- 2.4.3 Tug Service at Pad (Cryo's)
- 2.4.4 Final Checks at Pad
- 2.4.5 Remove Payload (Pad)
- 2.4.6 Payload Installation or Removal Preps (Pad)
- 2.4.7 Payload Installation (Pad)

3.1 SAFE AND SECURE

- 3.1.1 Tug Ground Safing at Safing Area
- 3.1.1a Tug Ground Safing at Safing Area

3.2 SHUTTLE/TUG DEMATE

- 3.2.3 Recover Tug at MCF
- 3.2.5 Recover Tug and S/C at MCF
- 3.2.6b Recover FSE (Cabin) Equipment (COMSEC)
- 3.2.7 Recover FSE (Payload Bay) Equipment

11.3.6 Ground Turnaround Operations Descriptions and Timelines

The operational timelines for ETR and WTR as summarized in section 11.3.3 were developed using the methodology described in section 11.3.1 and are presented in the pages following section 11.3.7.

As an example of how the decisions were made for where certain functions are performed, trade study sheets on Tug/Shuttle Demote and On Pad vs Off Pad Installation are inserted after the timelines. These sheets also provide the response to action items 98 and 139.

11.3.7 Task Description Sheets

The detailed timelines of section 11.3.6 consist of several hundred separate tasks. Each of these tasks, in turn, is described by a separate Task Description Sheet. Because of the volume of these sheets, they are not presented here but rather are included in appendix 11.10-D. Also included in appendix D is the baseline time line (which includes all operations for all options) from which the specific option time line was developed.

TASK TIMELINES

FOR

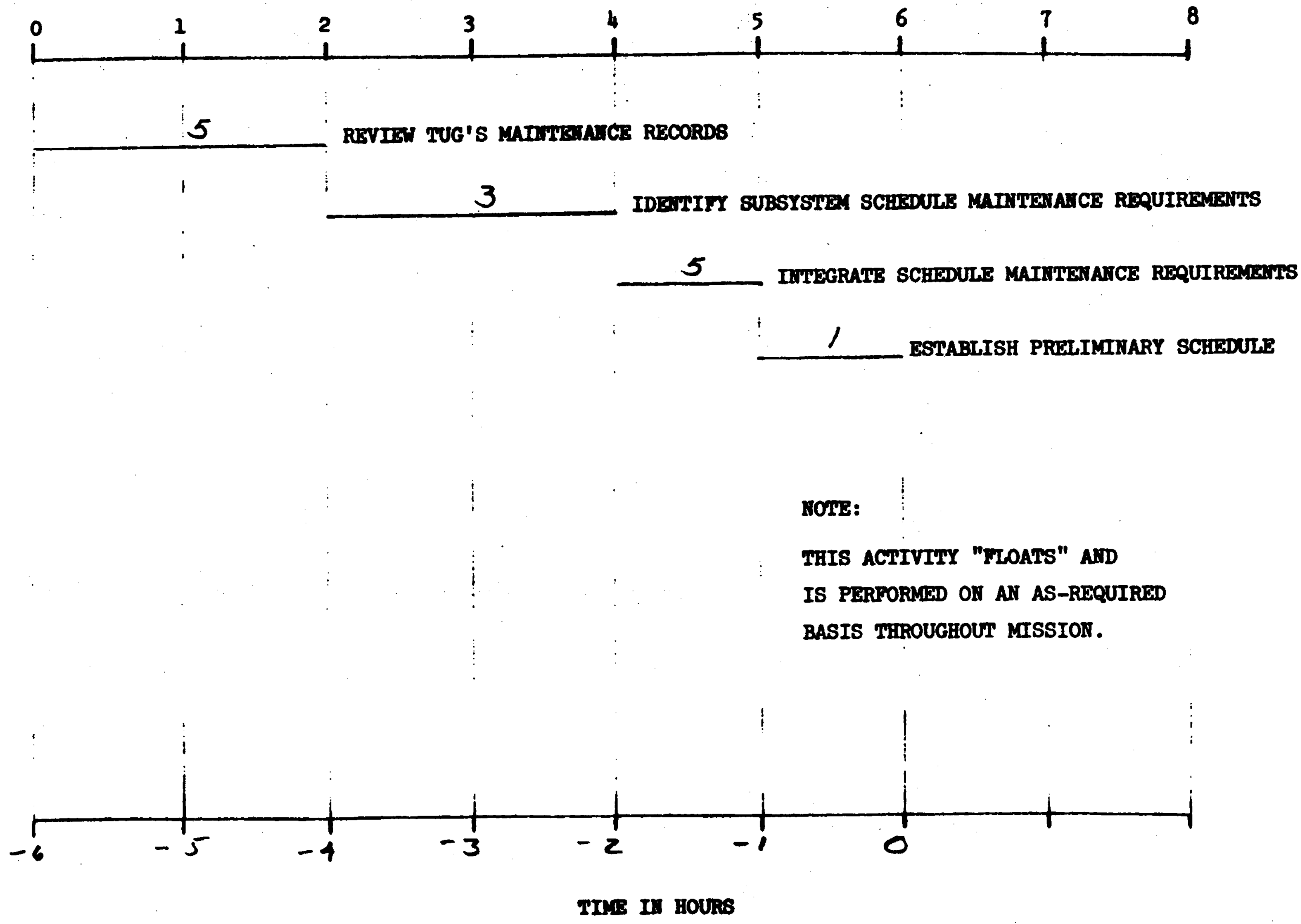
THE CRYOGENIC TUG

GROUND AND LAUNCH OPERATIONS

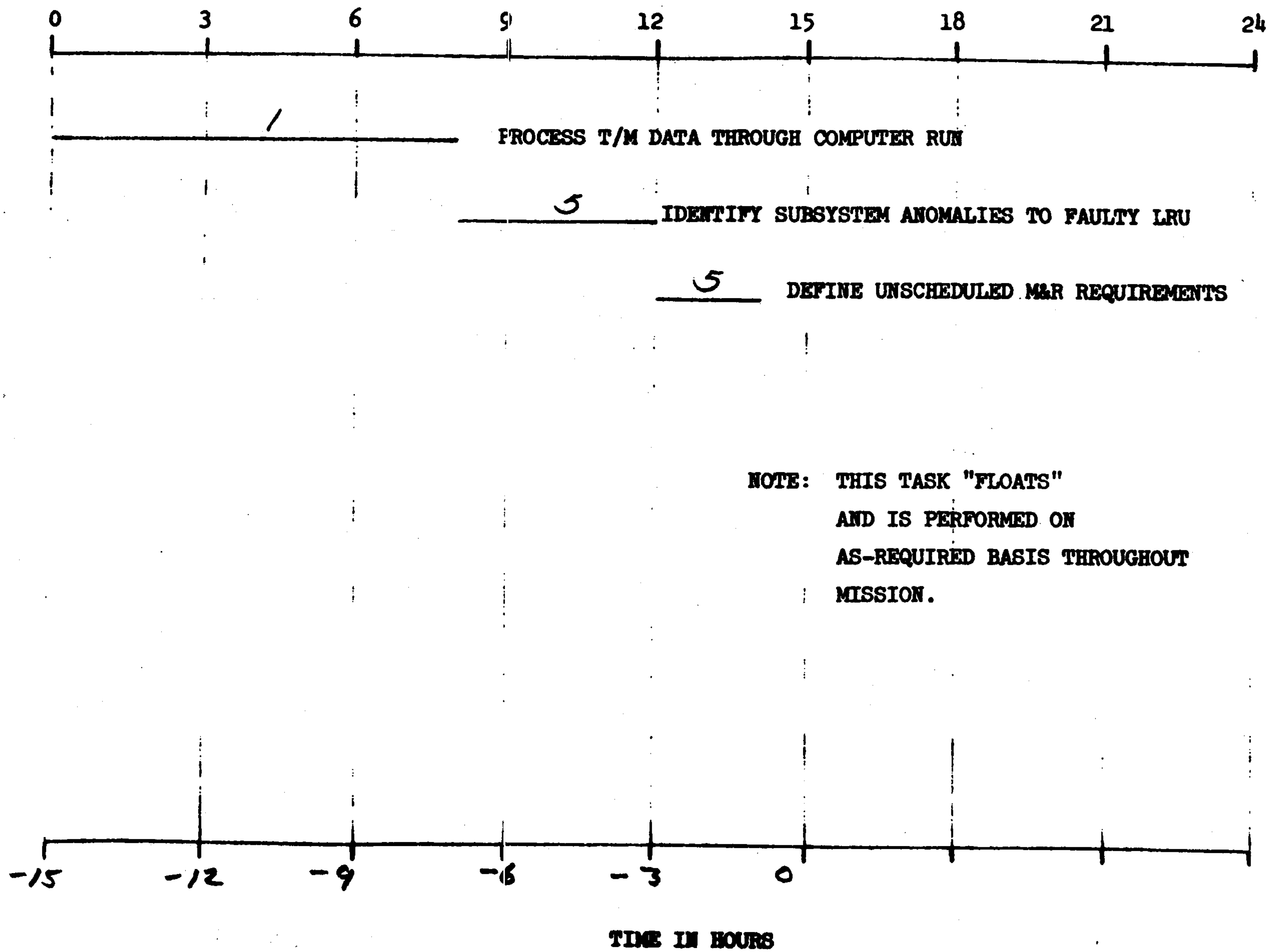
OPTION NO. 3I WTR

SEPTEMBER 1973

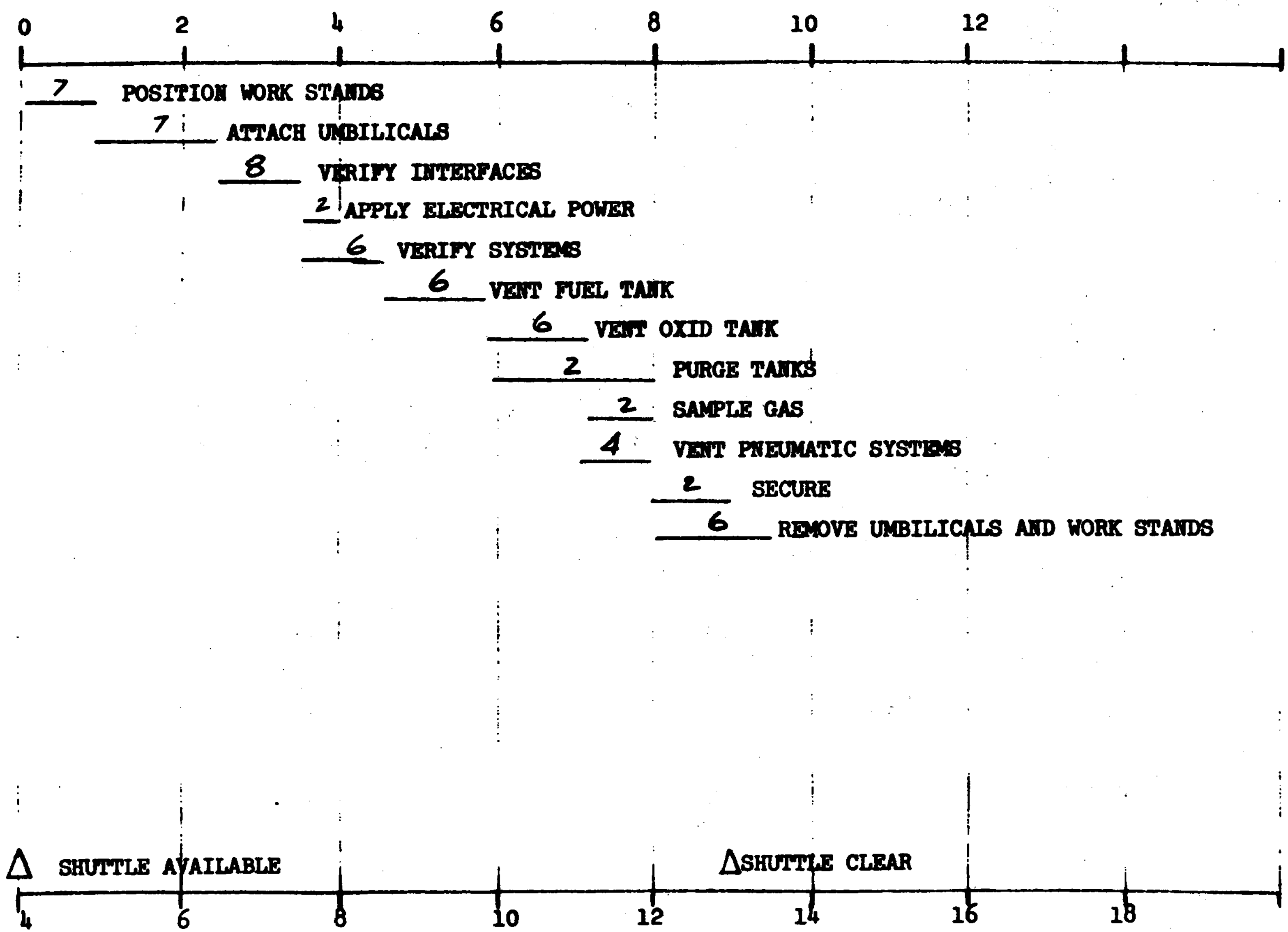
OPTION NUMBER 3I WTR	FUNCTION TITLE PREPARE PRELIMINARY M&R SCHEDULE	FLOW BLOCK NO. 1.1.1



OPTION NUMBER 3I WTR	FUNCTION TITLE ANALYZE T/M FOR UNSCHEDULE M&R	FLOW BLOCK NO. 1.1.2



OPTION NUMBER 3I WTR	FUNCTION TITLE TUG GROUND SAFING AT SAFING AREA	FLOW BLOCK NO. 3.1.1

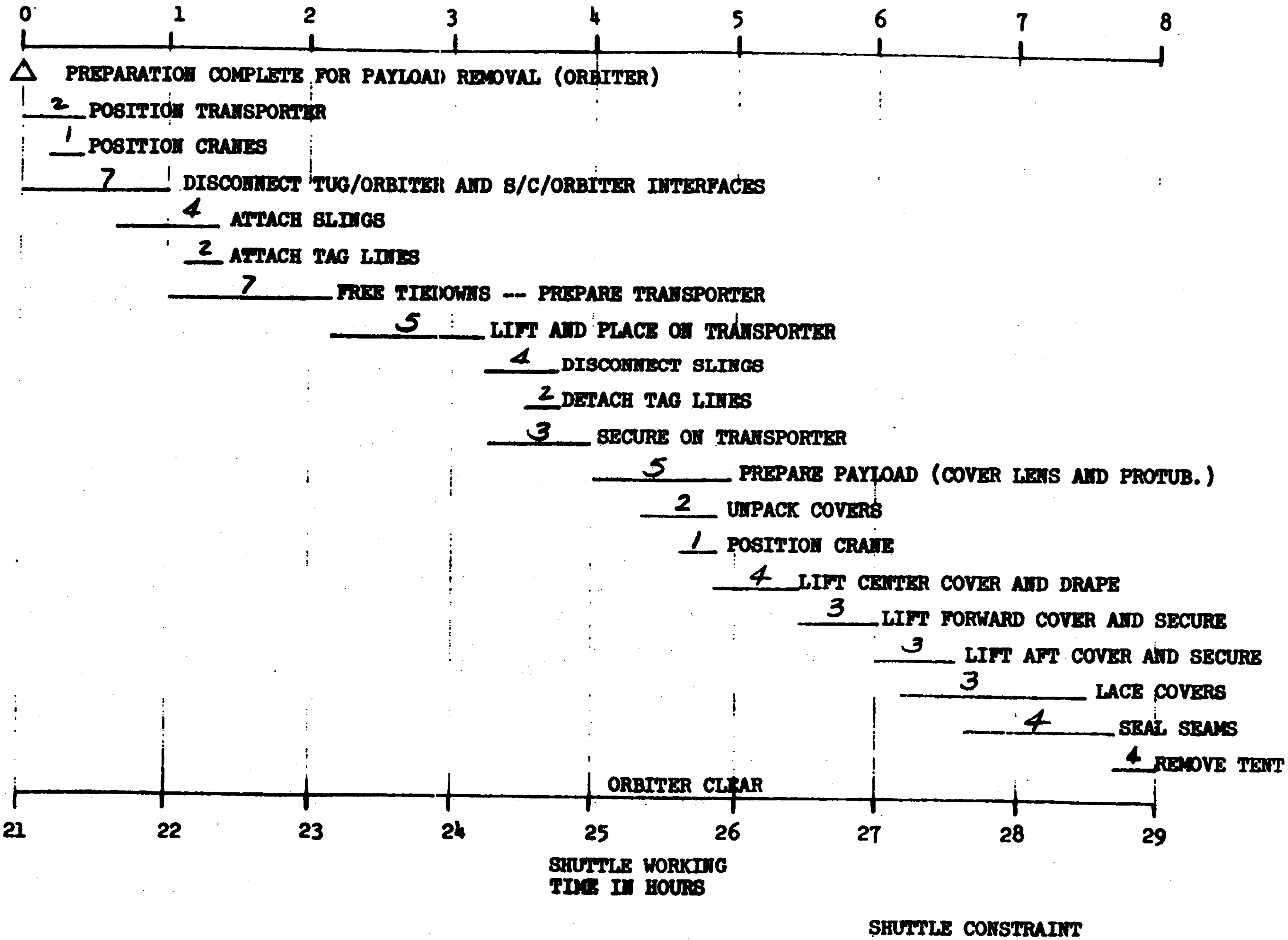


SHUTTLE WORKING
TIME IN HOURS

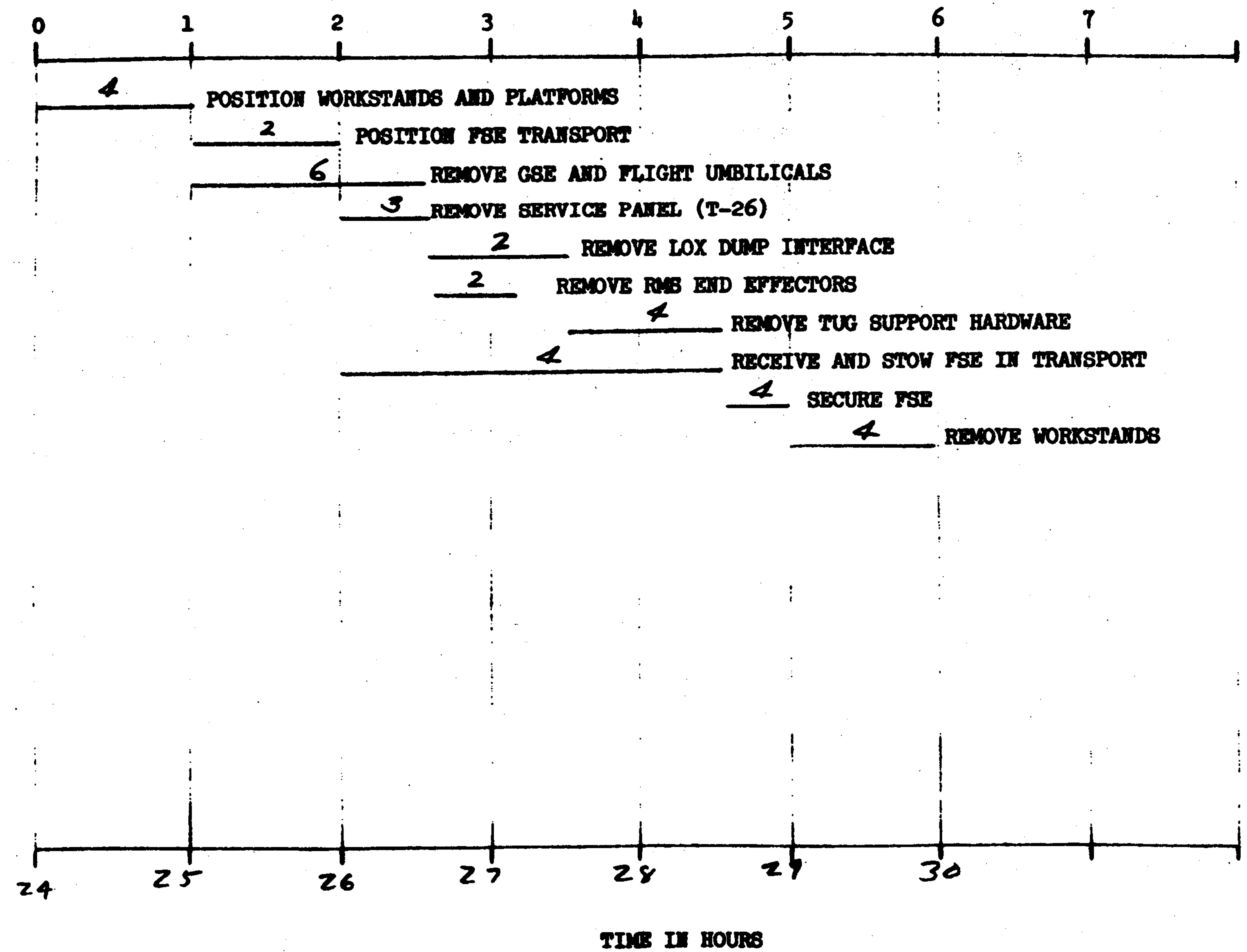
NOTE: NO RESIDUAL LIQUIDS

SHUTTLE CONSTRAINTS

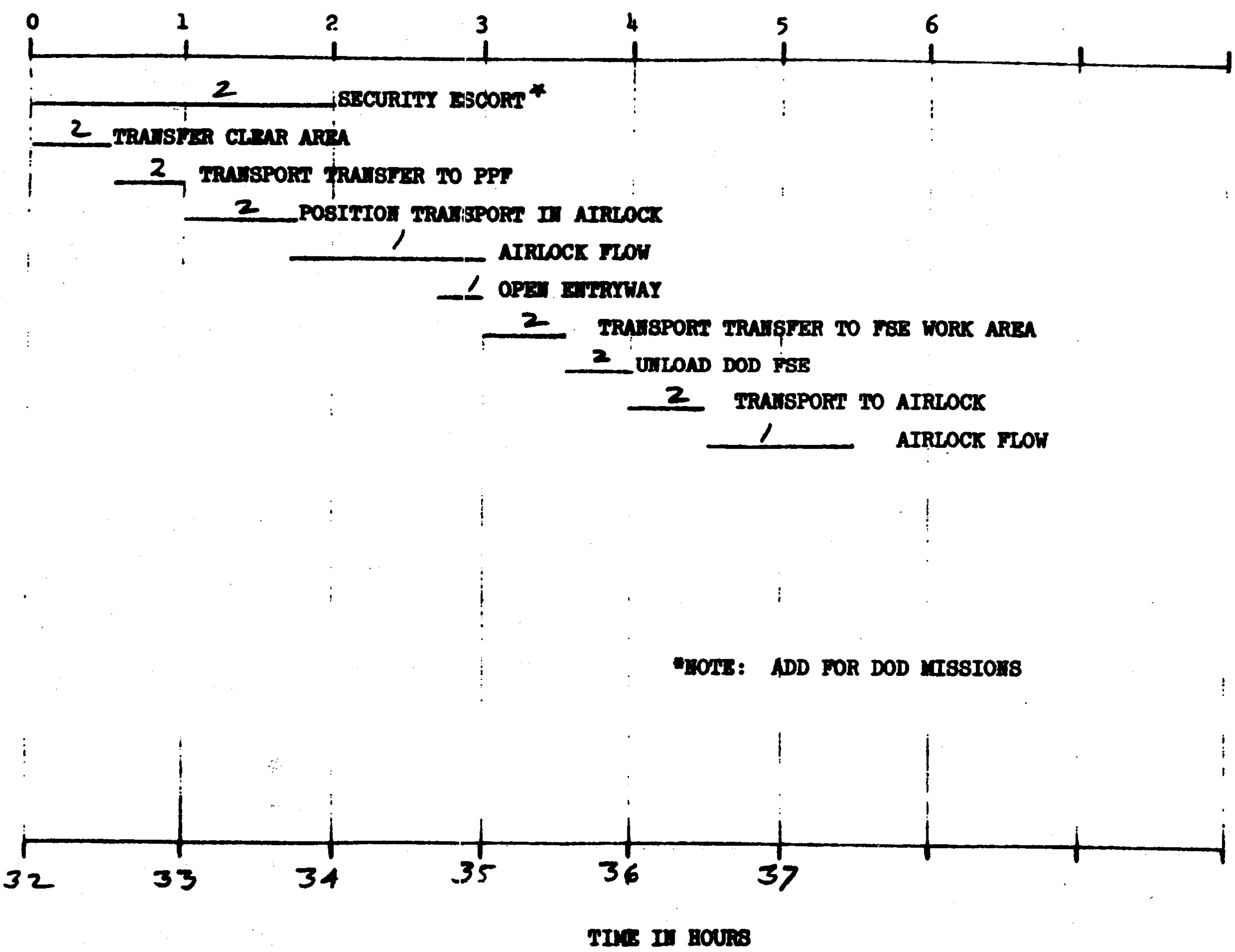
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I WTR	RECOVER TUG AND S/C AT MCF	3.2.5



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I WTR ALL	RECOVER FSE (PAYLOAD BAY) EQUIPMENT	3.2.7

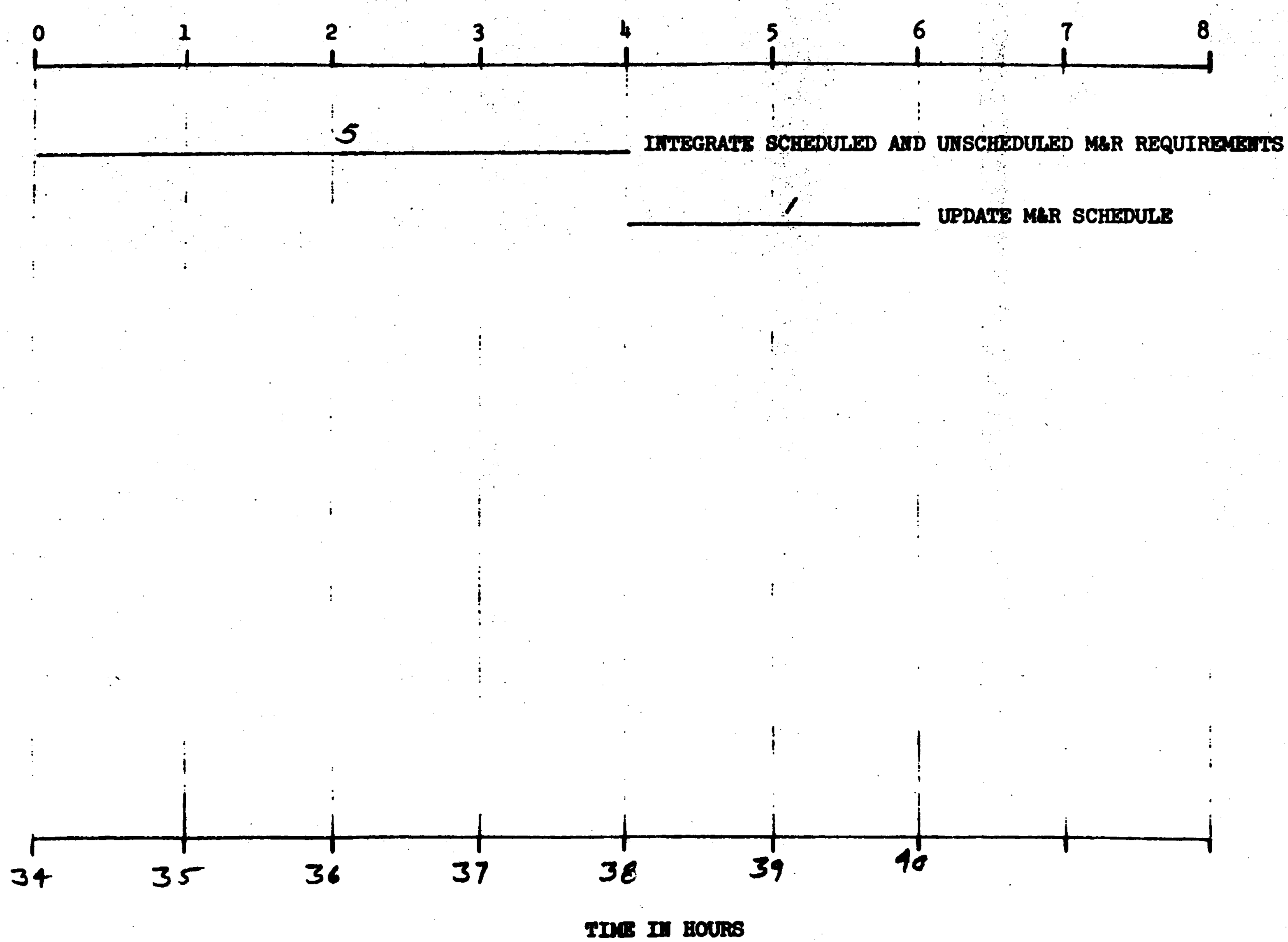


OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I WTR	TRANSFER FSE TO PPF	3.2.8

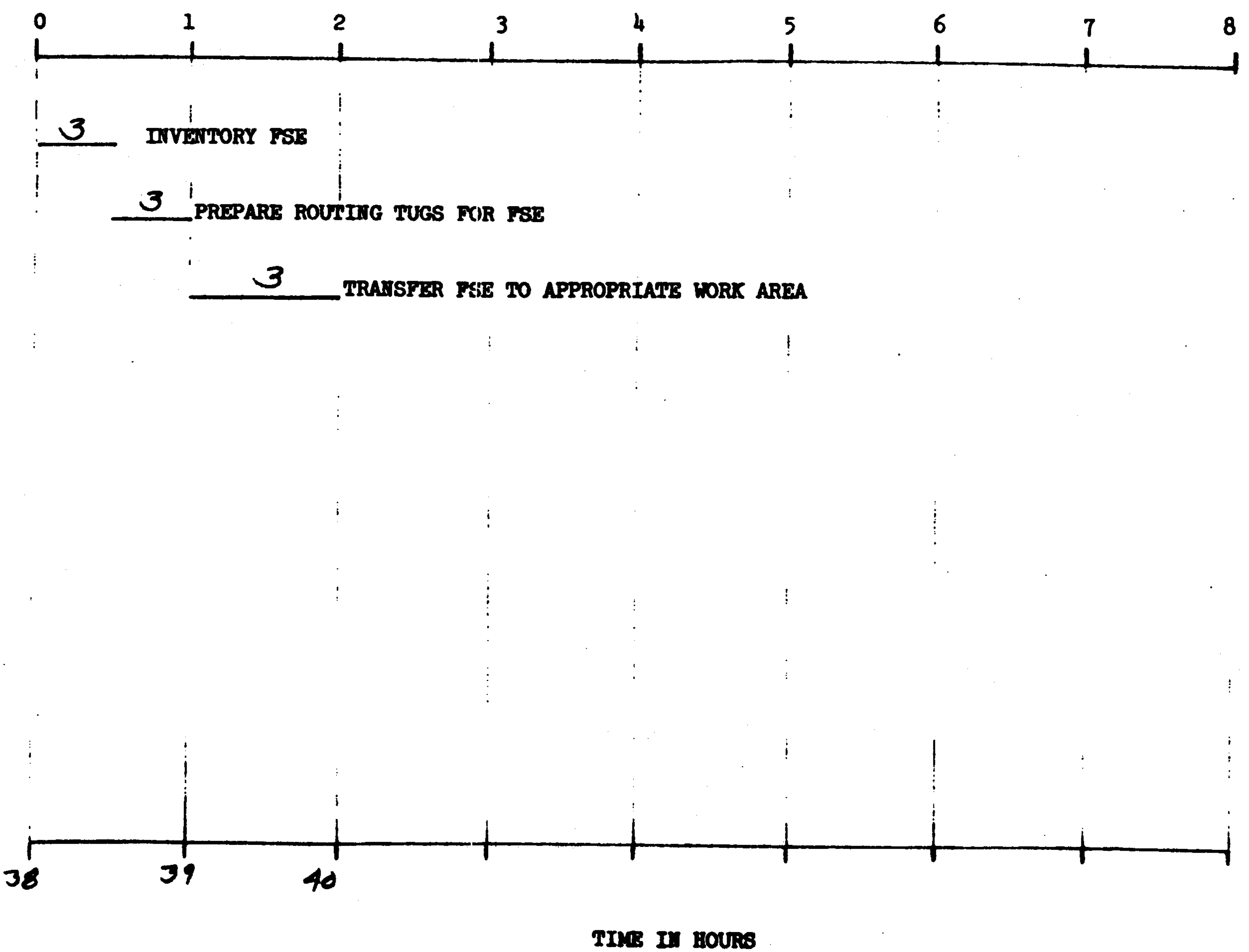


*NOTE: ADD FOR DOD MISSIONS

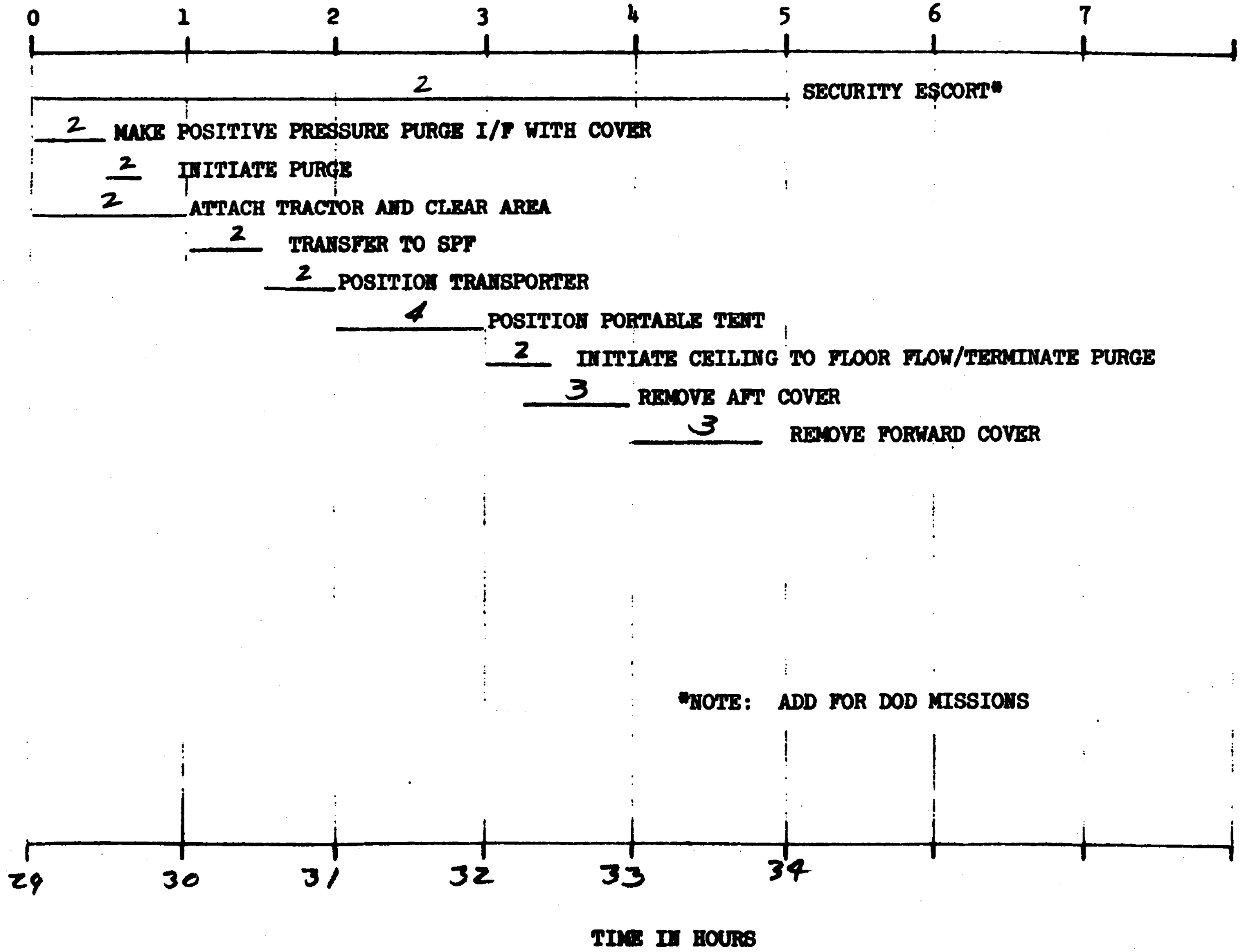
OPTION NUMBER 3I WTR	FUNCTION TITLE UPDATE M&R SCHEDULE	FLOW BLOCK NO. 1.1.3



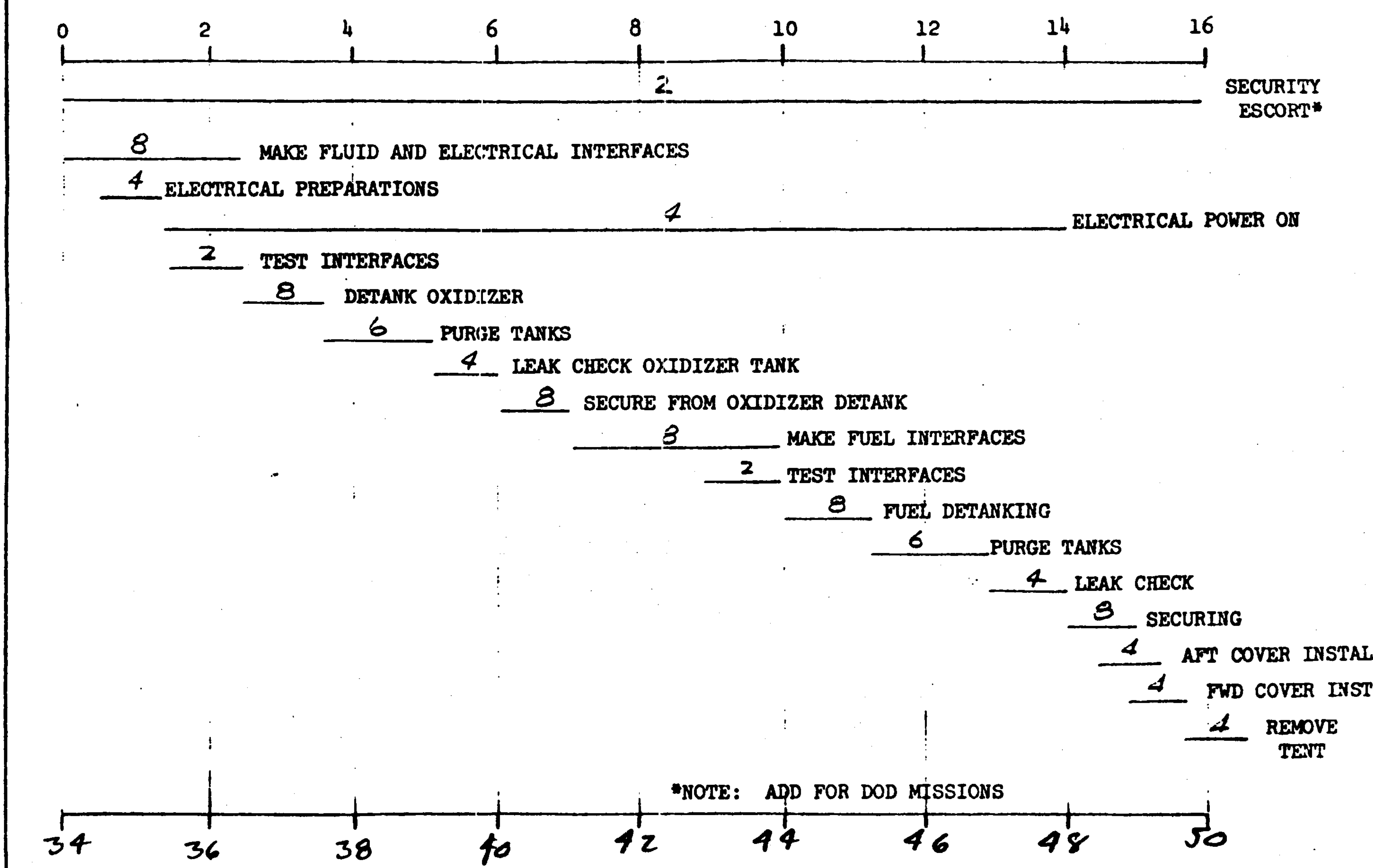
OPTION NUMBER 3I WTR	FUNCTION TITLE RECEIVE FSE AT TPF/PPF	FLOW BLOCK NO. 1.1.15



OPTION NUMBER 3I WTR	FUNCTION TITLE TRANSFER TUG AND S/C TO SPF	FLOW BLOCK NO. 3.1.4

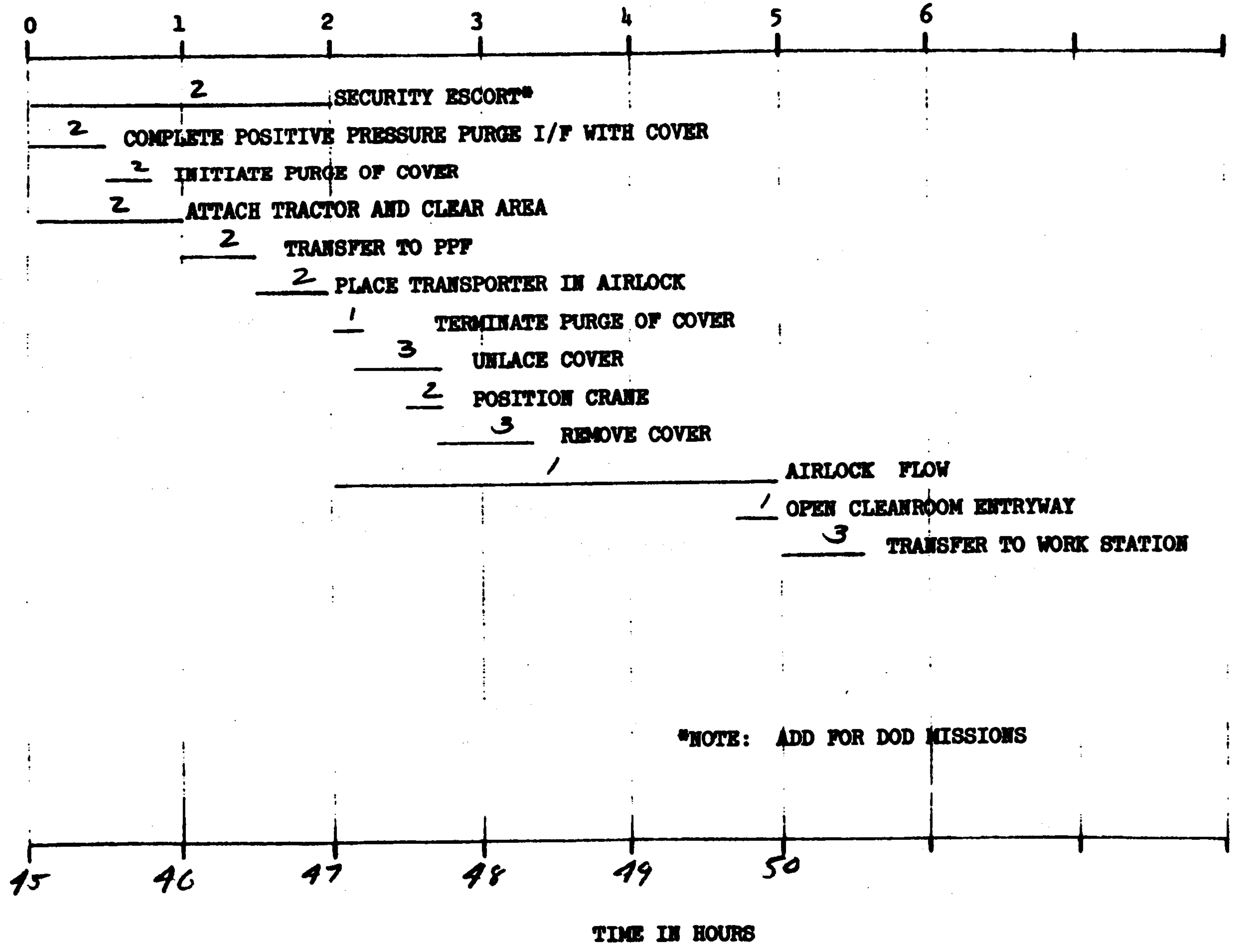


OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I WTR	TUG SAFING	3.1.7

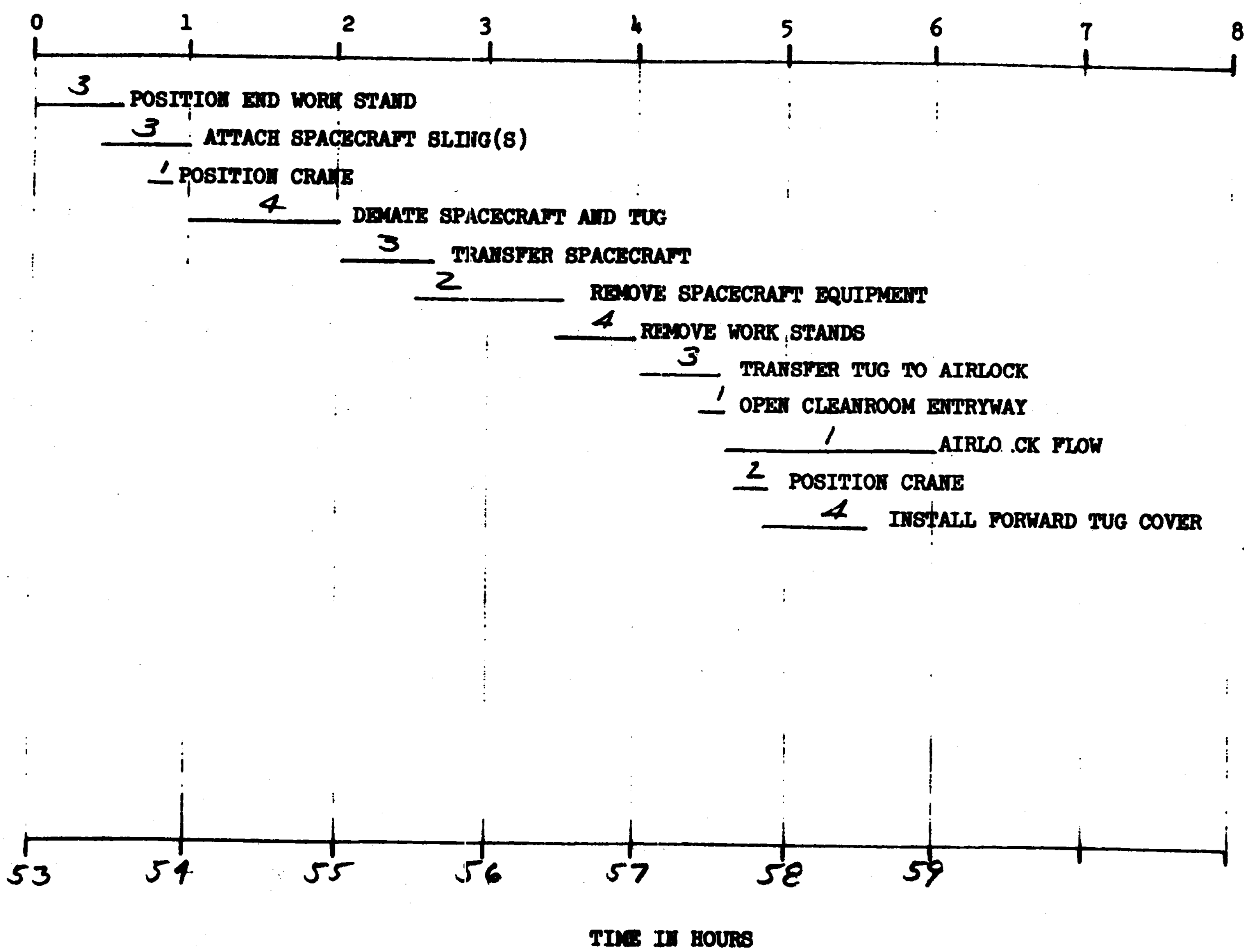


NOTES: BIPROPELLANT AT SPF

OPTION NUMBER 3I WTR	FUNCTION TITLE TRANSFER TUG TO PPF	FLOW BLOCK NO. 3.3.5



OPTION NUMBER 3I WTR	FUNCTION TITLE DEMATE TUG AND SPACECRAFT	FLOW BLOCK NO. 3.3.7



OPTION NUMBER 3I WTR	FUNCTION TITLE RECEIVE TUG AT TPF/PPF	FLOW BLOCK NO. 1.1.4

0 1 2 3 4 5 6 7 8

3 POSITION TUG (ON TRANSPORTER) AND ESTABLISH AND VERIFY ELECTRICAL GROUND

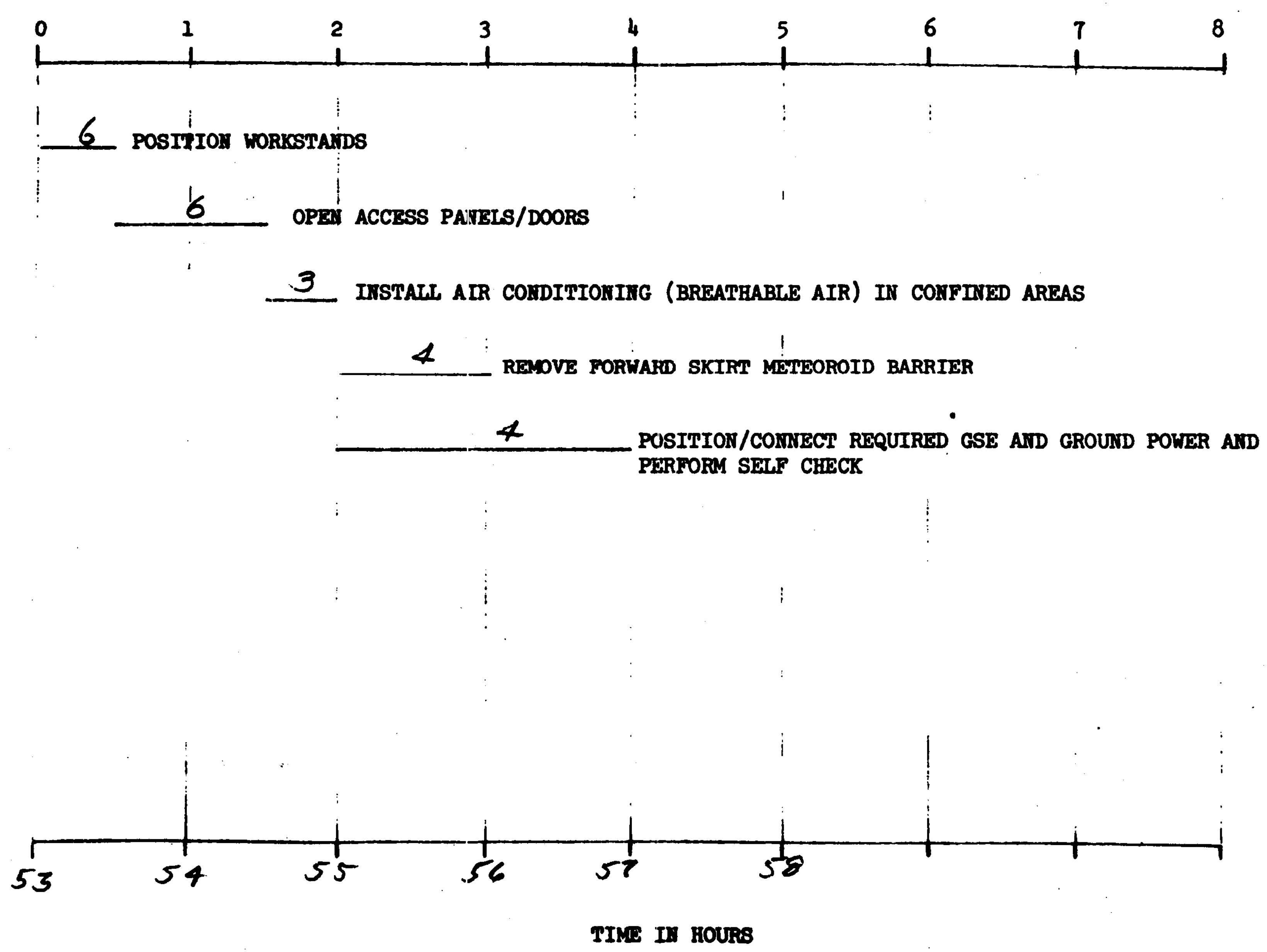
3 REMOVE PROTECTIVE COVERS

2 PERFORM SAFETY CHECK

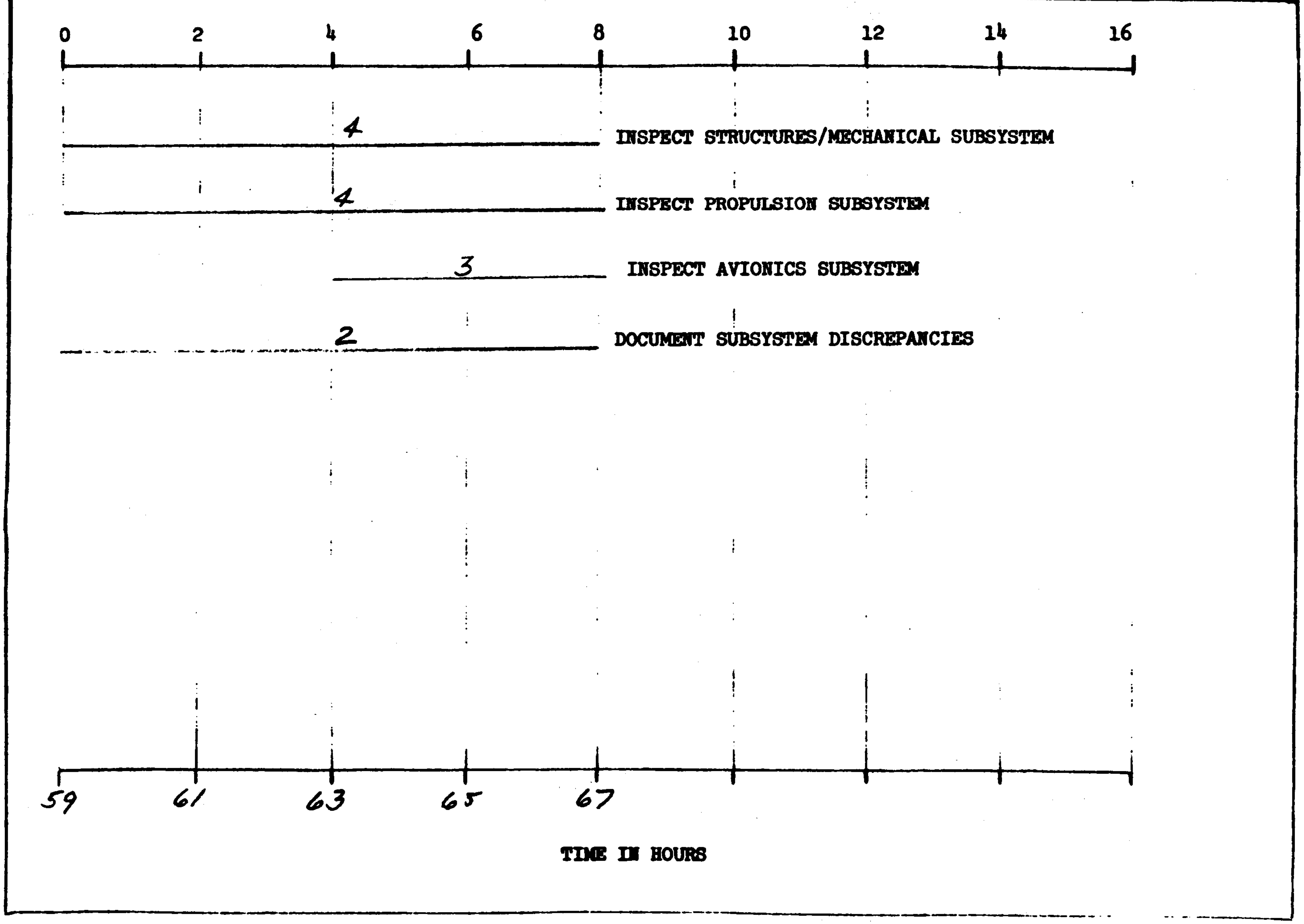
51 52 53

TIME IN HOURS

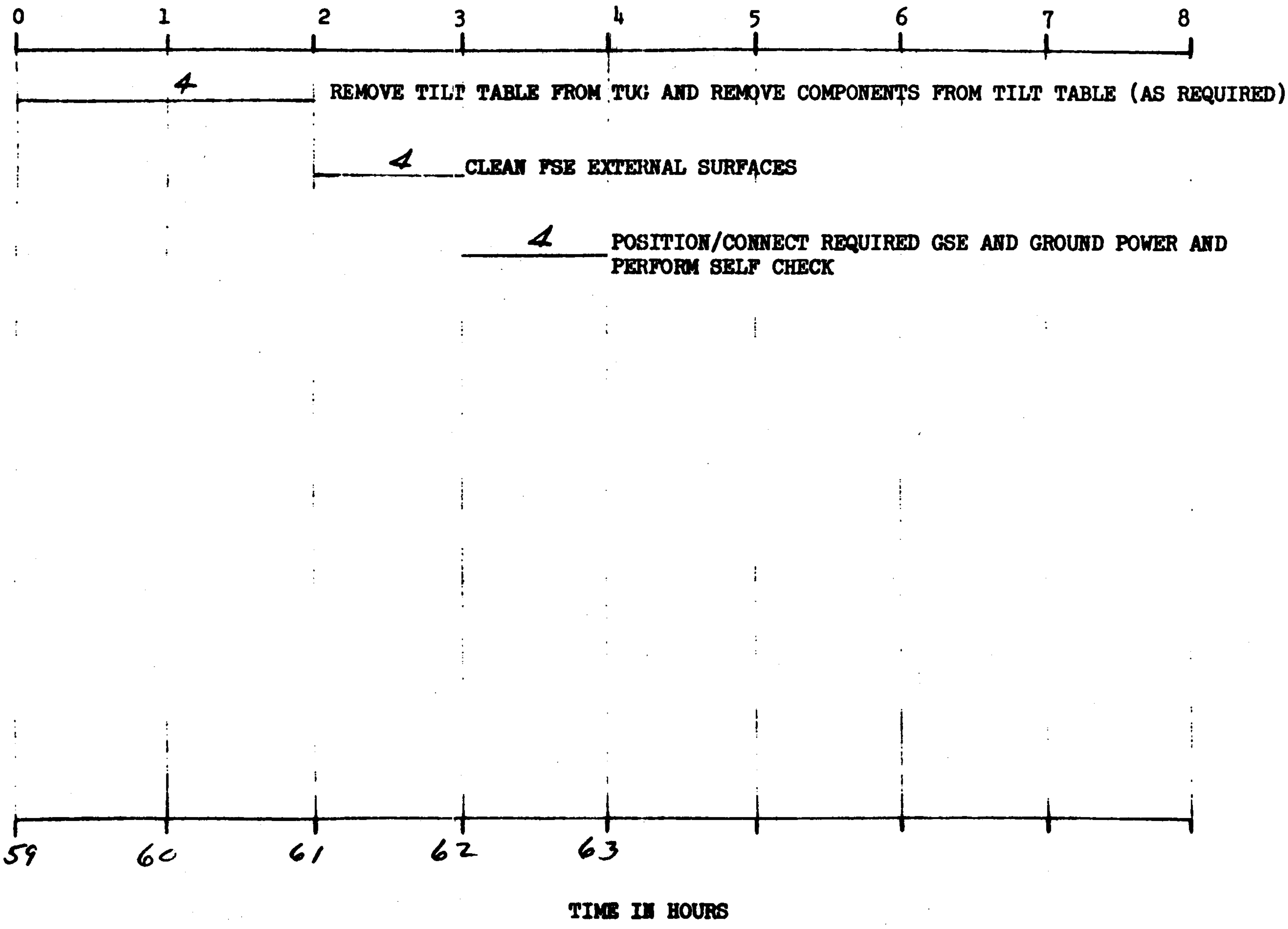
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I WTR	PREPARE FOR INSPECTION AND C/O	1.1.5



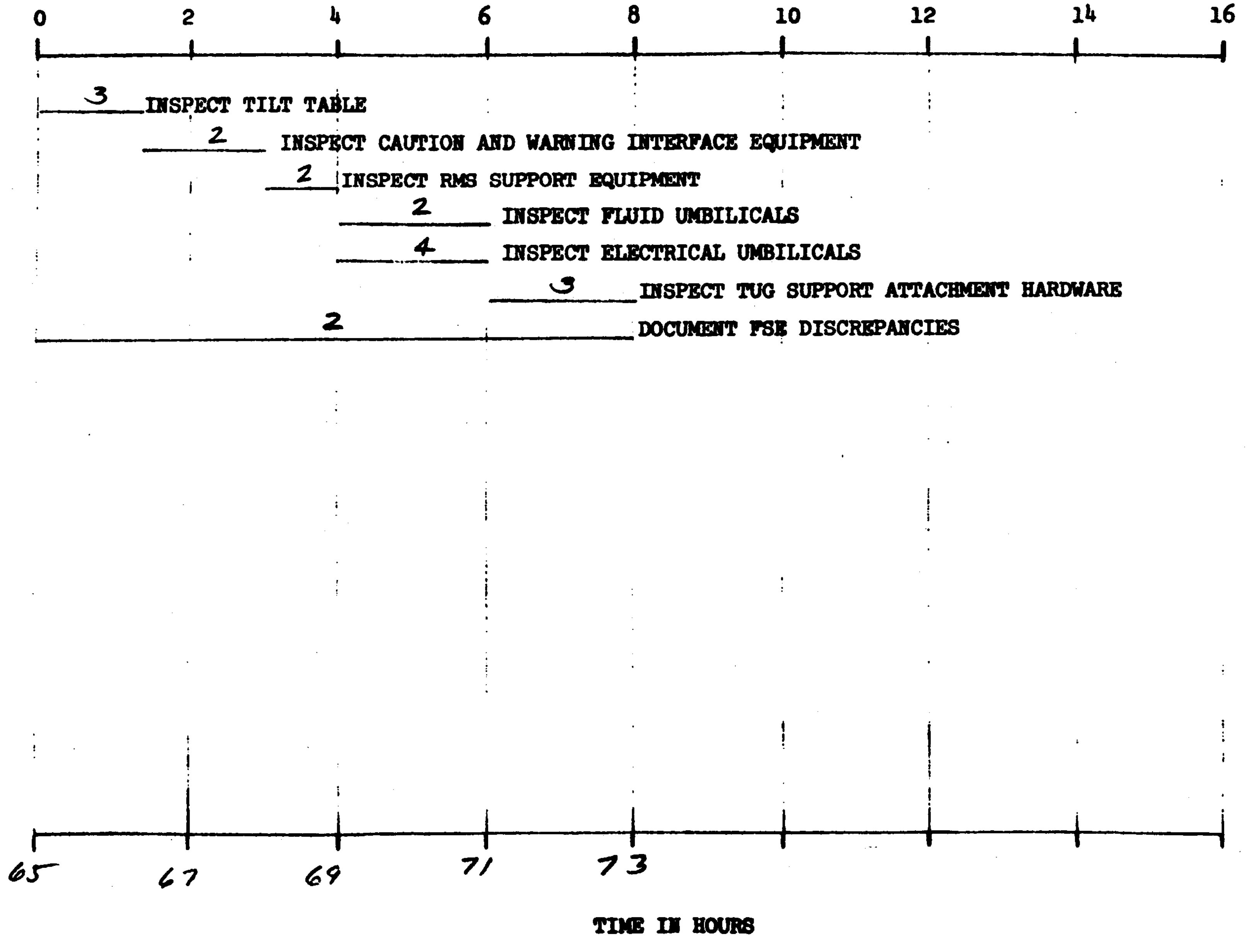
OPTION NUMBER	3I WTR	FUNCTION TITLE	PERFORM POST FLIGHT RECEIVING INSPECTION	FLOW BLOCK NO.	1.1.6



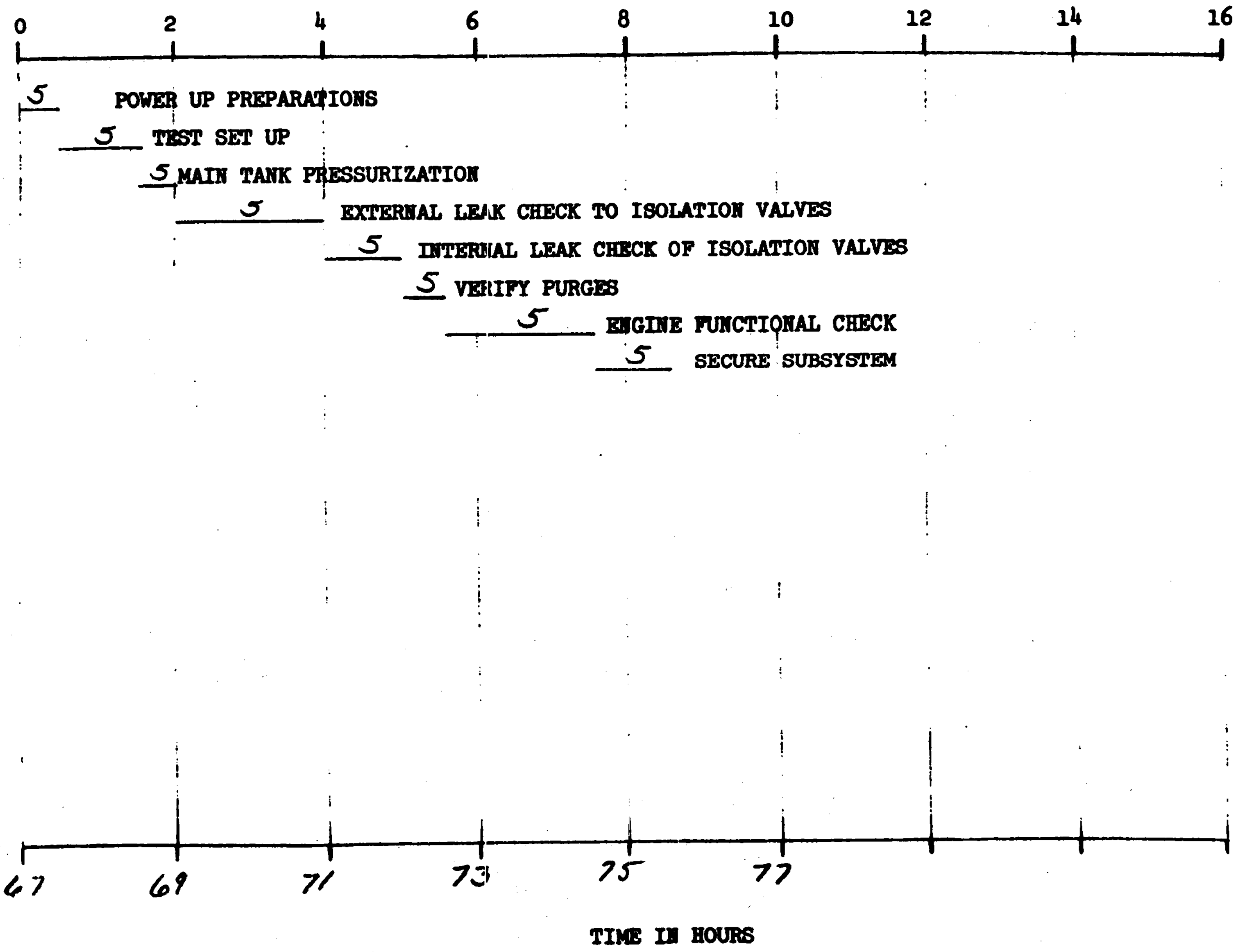
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I WTR	PREPARE FOR INSPECTION	1.1.16



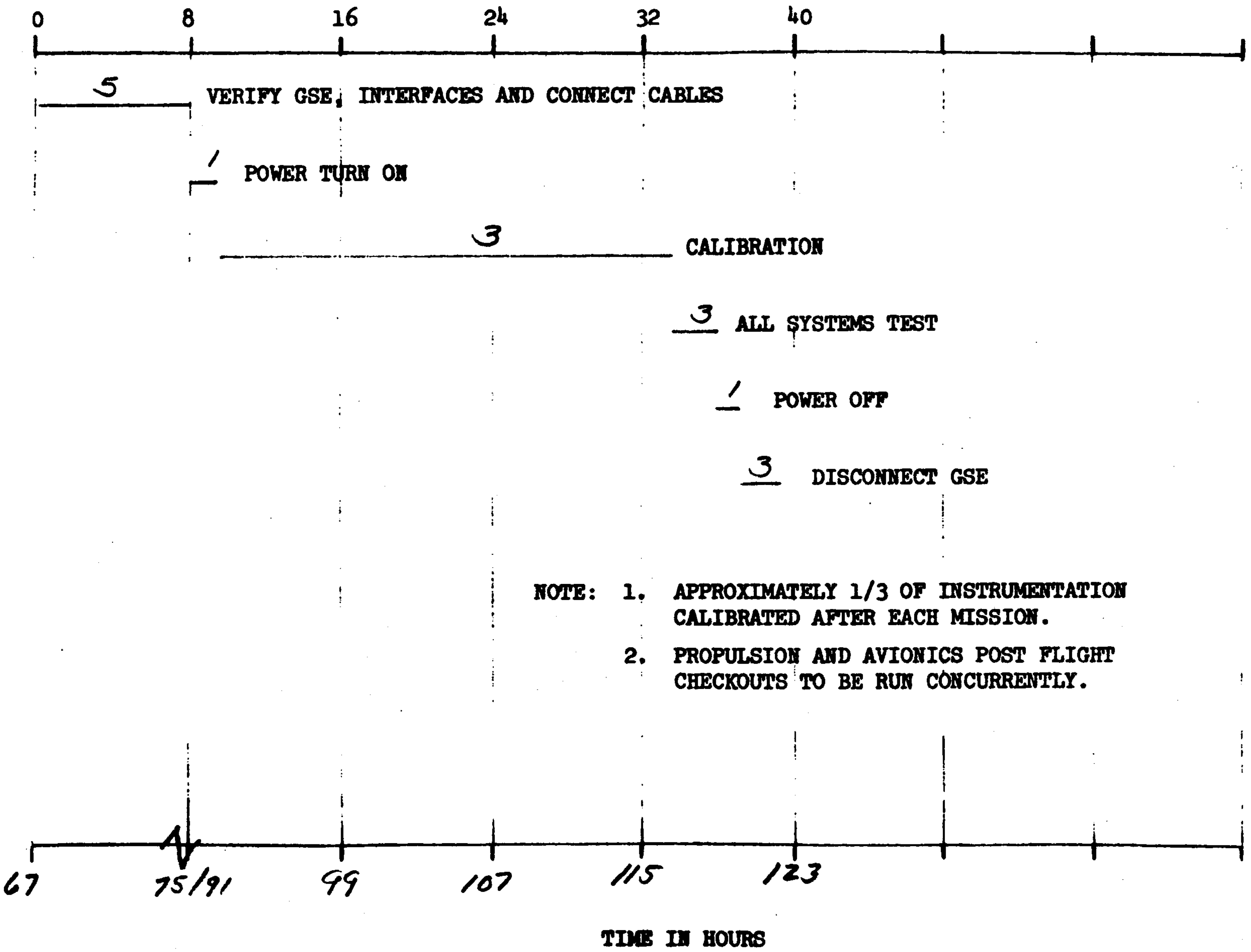
OPTION NUMBER 3I WTR	FUNCTION TITLE PERFORM FSE POST FLIGHT/RECEIVING INSPECTION	FLOW BLOCK NO. 1.1.17



OPTION NUMBER 3I WTR	FUNCTION TITLE POST FLIGHT CHECKOUT - MAIN PROPULSION PRESSURIZATION - AMBIENT HELIUM & GH_2 BLEED	FLOW BLOCK NO. 1.1.7.1



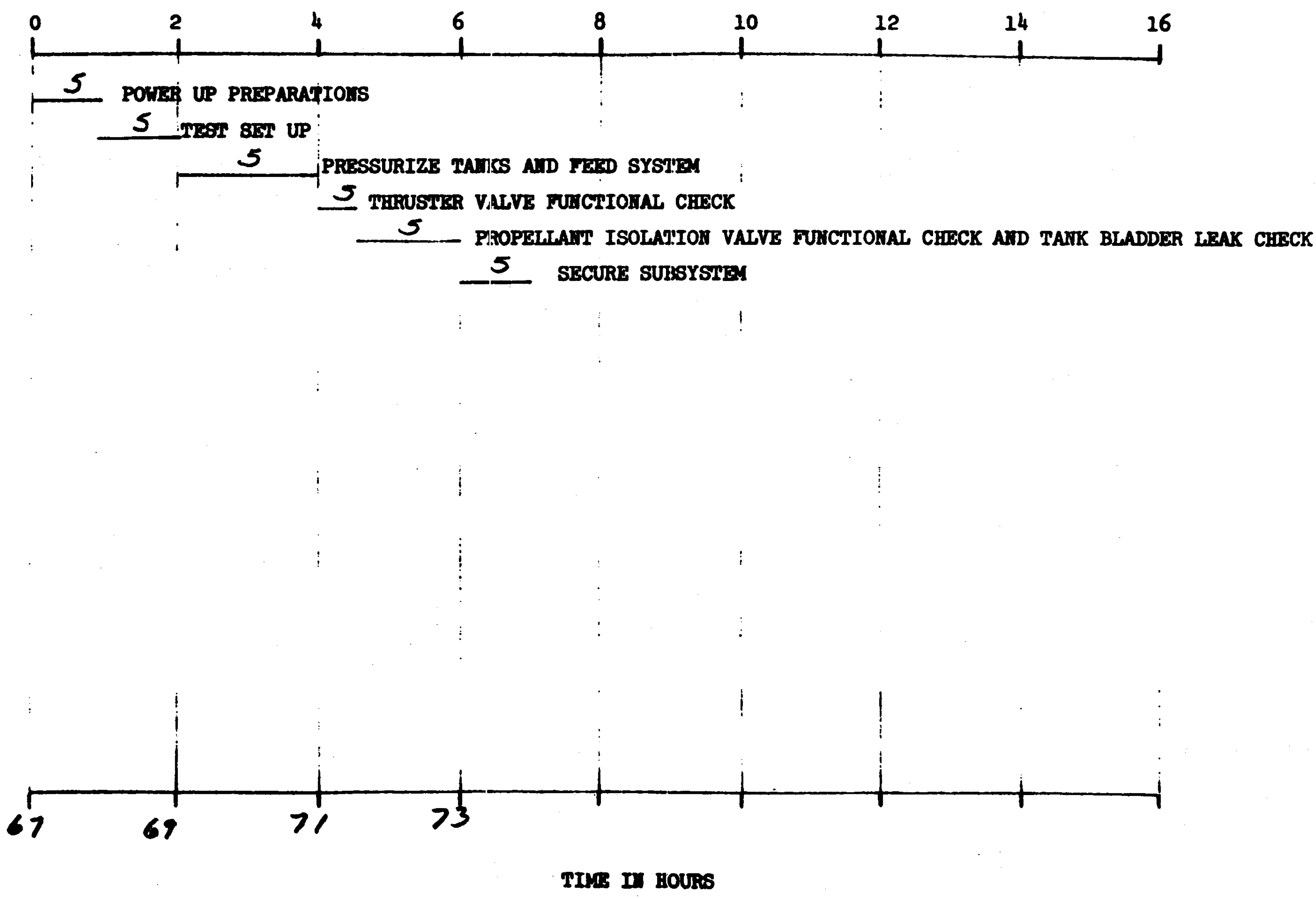
OPTION NUMBER 3I WTR	FUNCTION TITLE POST FLIGHT CHECKOUT - AVIONICS	FLOW BLOCK NO. 1.1.7.9



NOTE: 1. APPROXIMATELY 1/3 OF INSTRUMENTATION CALIBRATED AFTER EACH MISSION.

2. PROPULSION AND AVIONICS POST FLIGHT CHECKOUTS TO BE RUN CONCURRENTLY.

OPTION NUMBER	3I WTR	FUNCTION TITLE	POST FLIGHT CHECKOUT - APS SUBSYSTEM - MONOPROPELLANT - BLOWDOWN	FLOW BLOCK NO.	1.1.7.5



OPTION NUMBER 3I WTR	FUNCTION TITLE POST FLIGHT CHECKOUT - APS SUBSYSTEM MONOPROPELLANT - PRESSURIZED	FLOW BLOCK NO. 1.1.7.6

0 2 4 6 8 10 12 14 16

5 POWER UP PREPARATIONS

5 TEST SET UP

5 PRESSURIZE HELIUM BOTTLE

5 HIGH PRESSURE EXTERNAL LEAK CHECK

5 REGULATOR AND ISOLATION VALVE FUNCTIONAL AND INTERNAL LEAK CHECK - REGULATE PRESSURE AND LOCK UP

5 PRESSURE SWITCH CHECKOUT

5 PRESSURIZE LOW PRESSURE SYSTEM

5 THRUSTER VALVE FUNCTIONAL CHECK

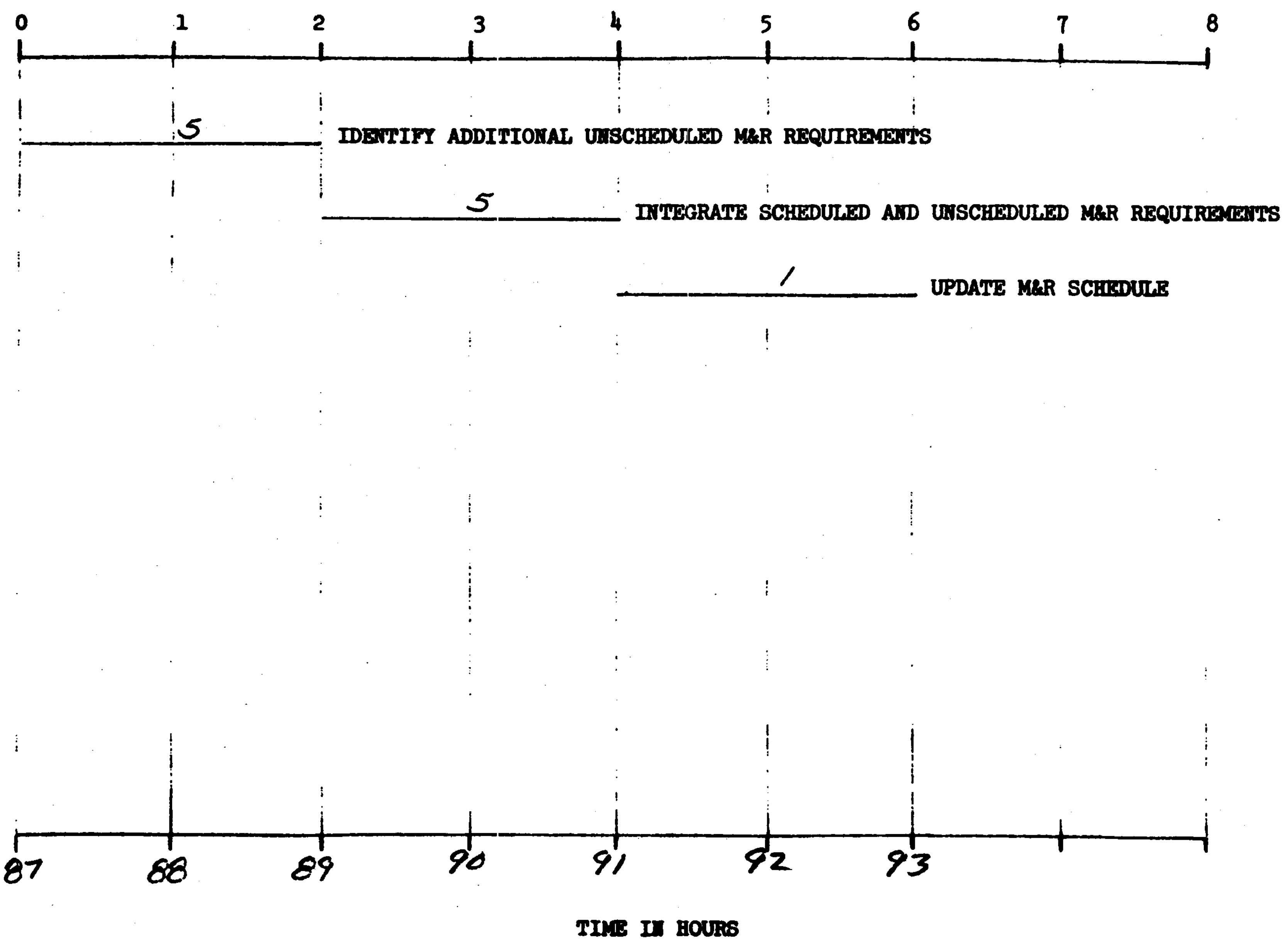
5 PROPELLANT ISOLATION VALVE FUNCTIONAL AND TANK BLADDER LEAK CHECK

5 SECURE SUBSYSTEM

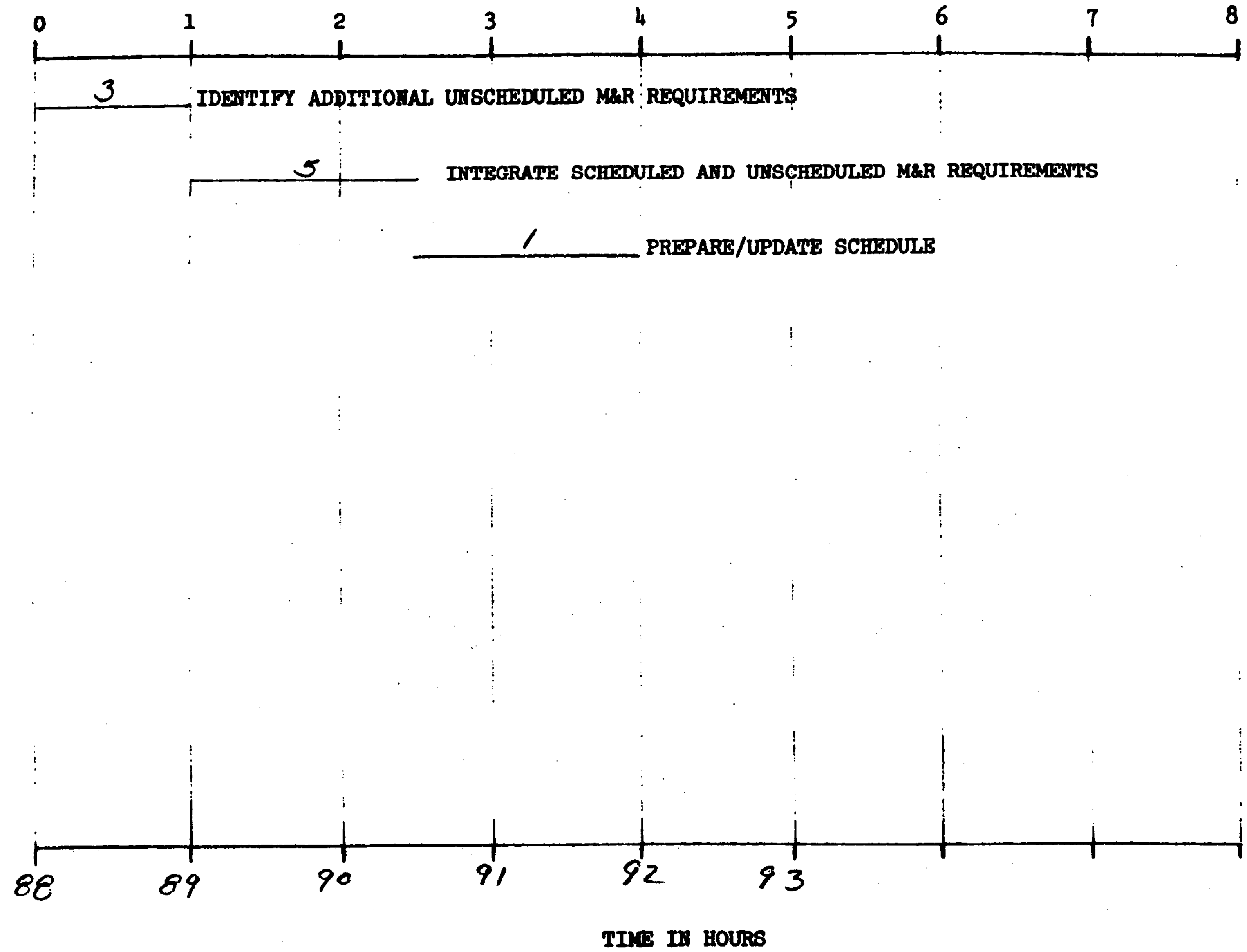
74 76 78 80 82 84 86

TIME IN HOURS

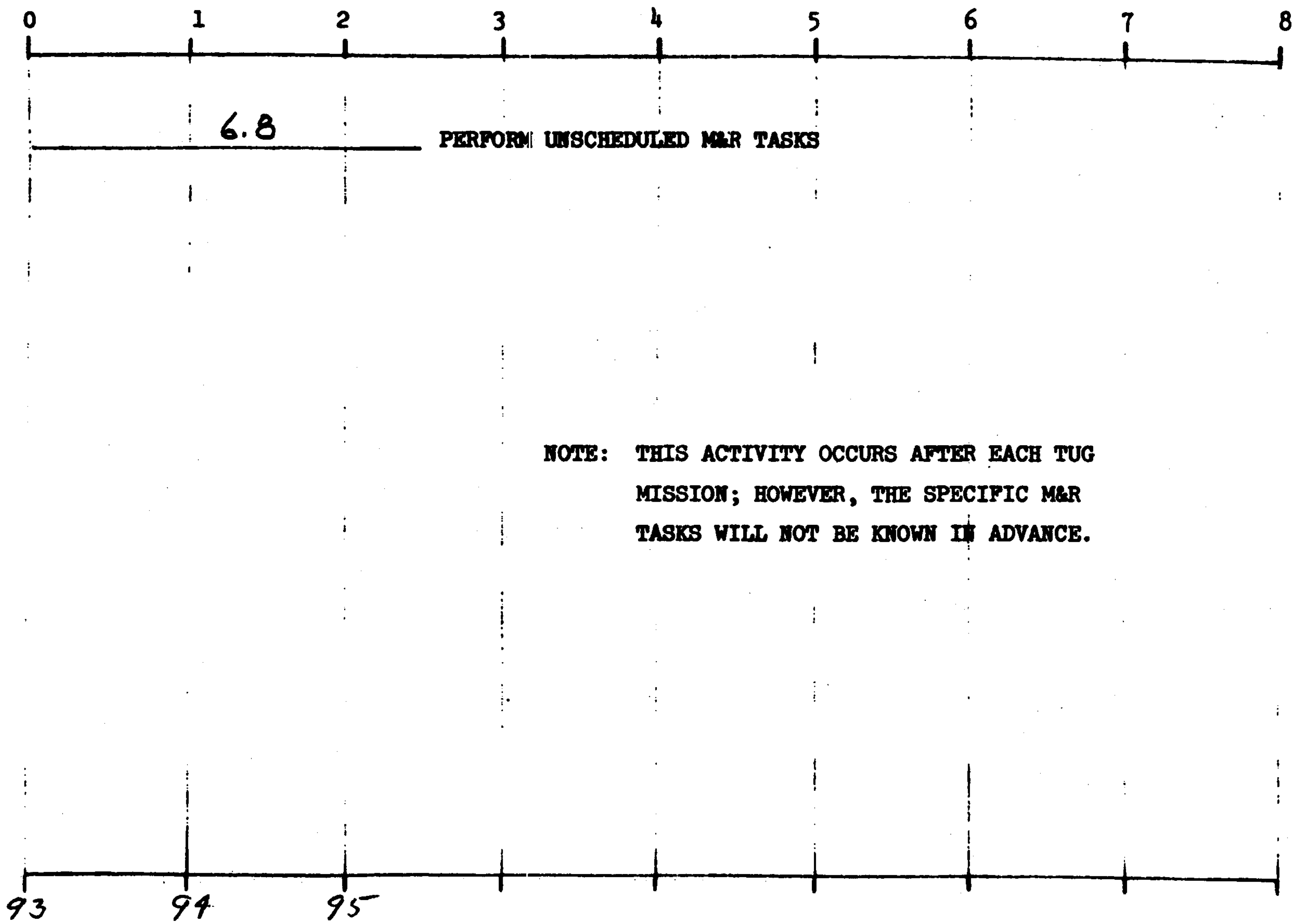
OPTION NUMBER	3I WTR	FUNCTION TITLE	PREPARE/UPDATE M&R SCHEDULE	FLOW BLOCK NO.	1.1.10



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I WTR	PREPARE/UPDATE M&R SCHEDULE	1.1.18



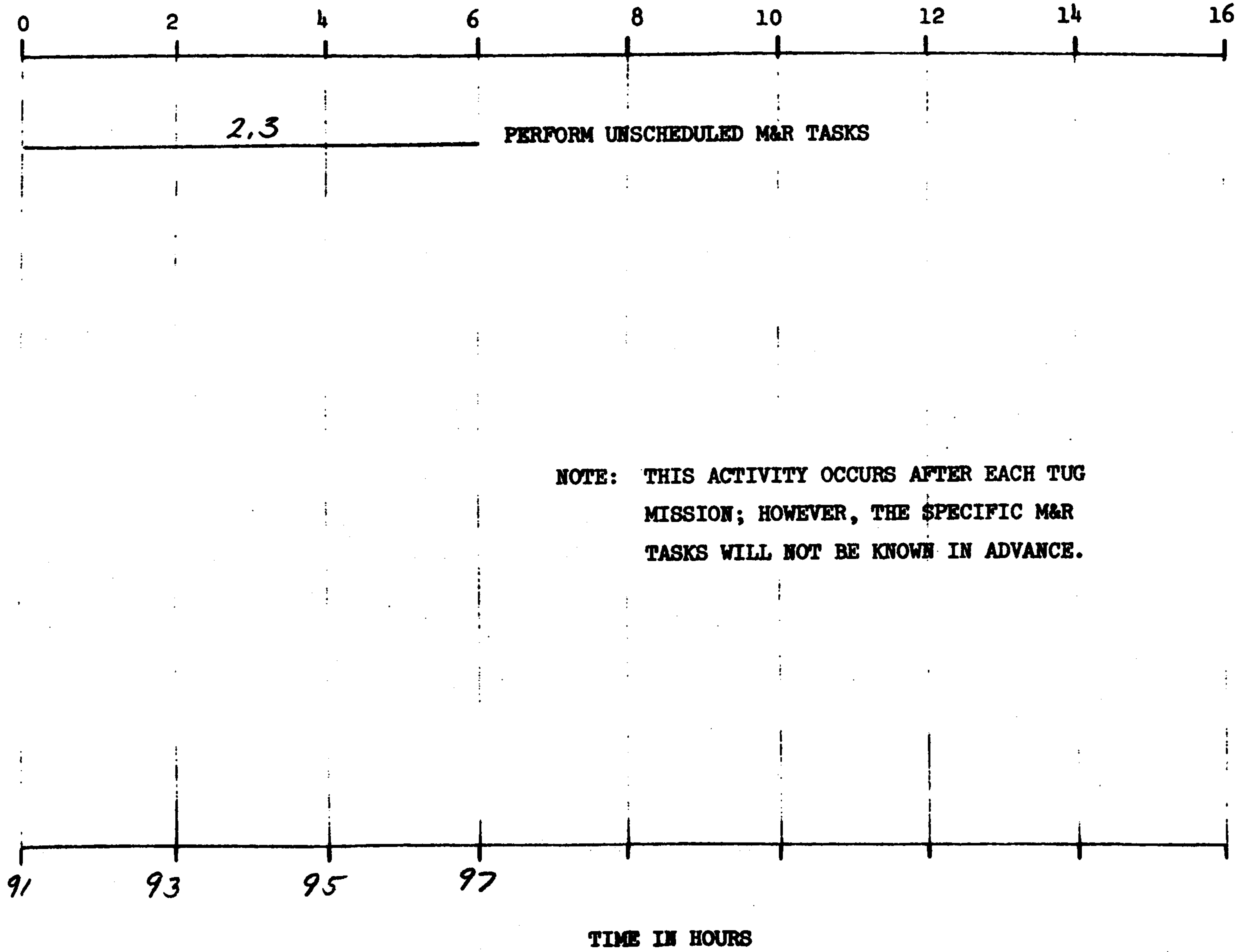
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I WTR	PERFORM STRUCTURAL/MECHANICAL M&R	1.1.11



NOTE: THIS ACTIVITY OCCURS AFTER EACH TUG MISSION; HOWEVER, THE SPECIFIC M&R TASKS WILL NOT BE KNOWN IN ADVANCE.

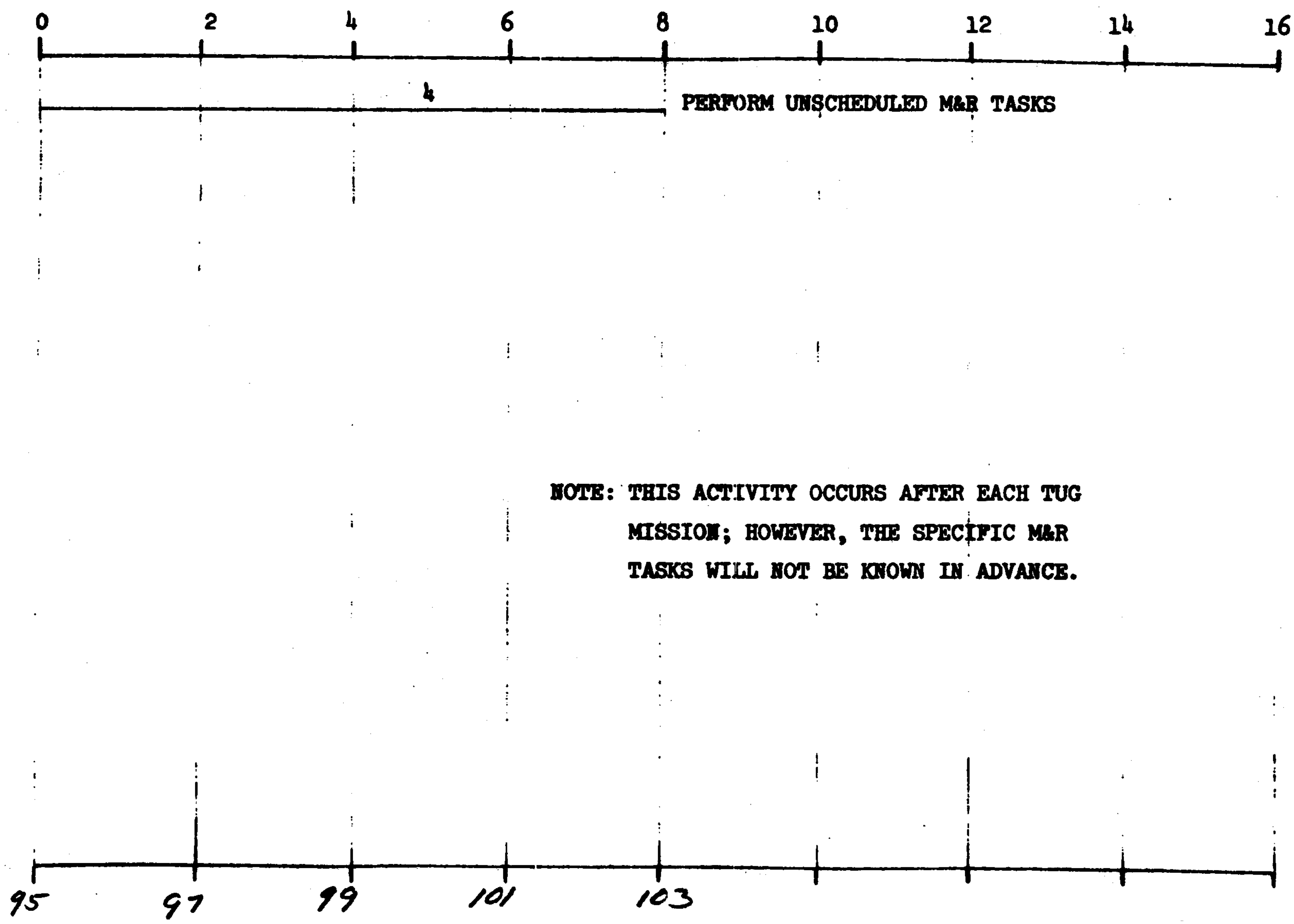
TIME IN HOURS

OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I WTR	PERFORM PROPULSION M&R	1.1.12



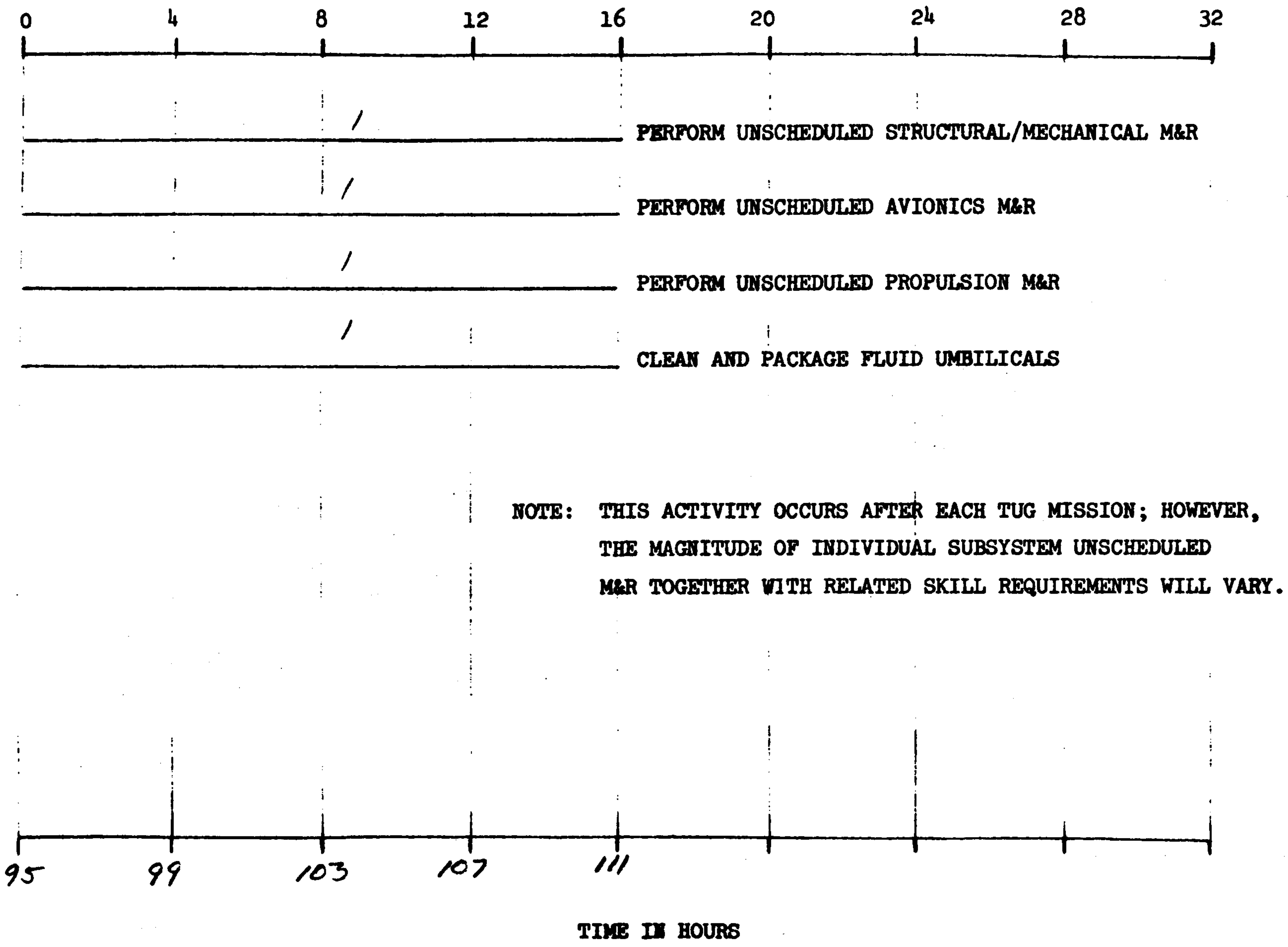
NOTE: THIS ACTIVITY OCCURS AFTER EACH TUG MISSION; HOWEVER, THE SPECIFIC M&R TASKS WILL NOT BE KNOWN IN ADVANCE.

OPTION NUMBER 3I WTR	FUNCTION TITLE PERFORM AVIONICS M&R	FLOW BLOCK NO. 1.1.13



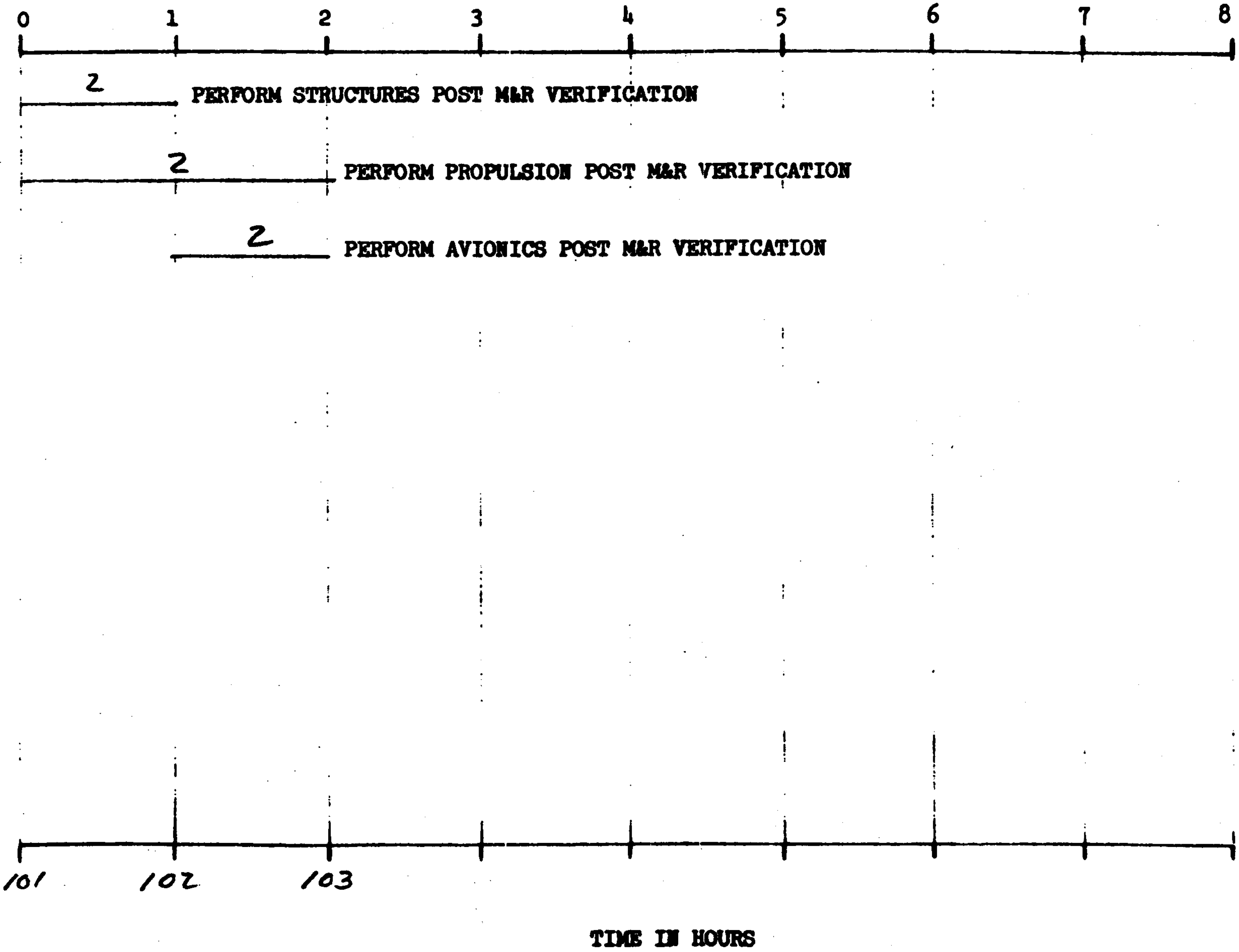
NOTE: THIS ACTIVITY OCCURS AFTER EACH TUG MISSION; HOWEVER, THE SPECIFIC M&R TASKS WILL NOT BE KNOWN IN ADVANCE.

OPTION NUMBER 3I WTR	FUNCTION TITLE PERFORM FSE M&R	FLOW BLOCK NO. 1.1.19

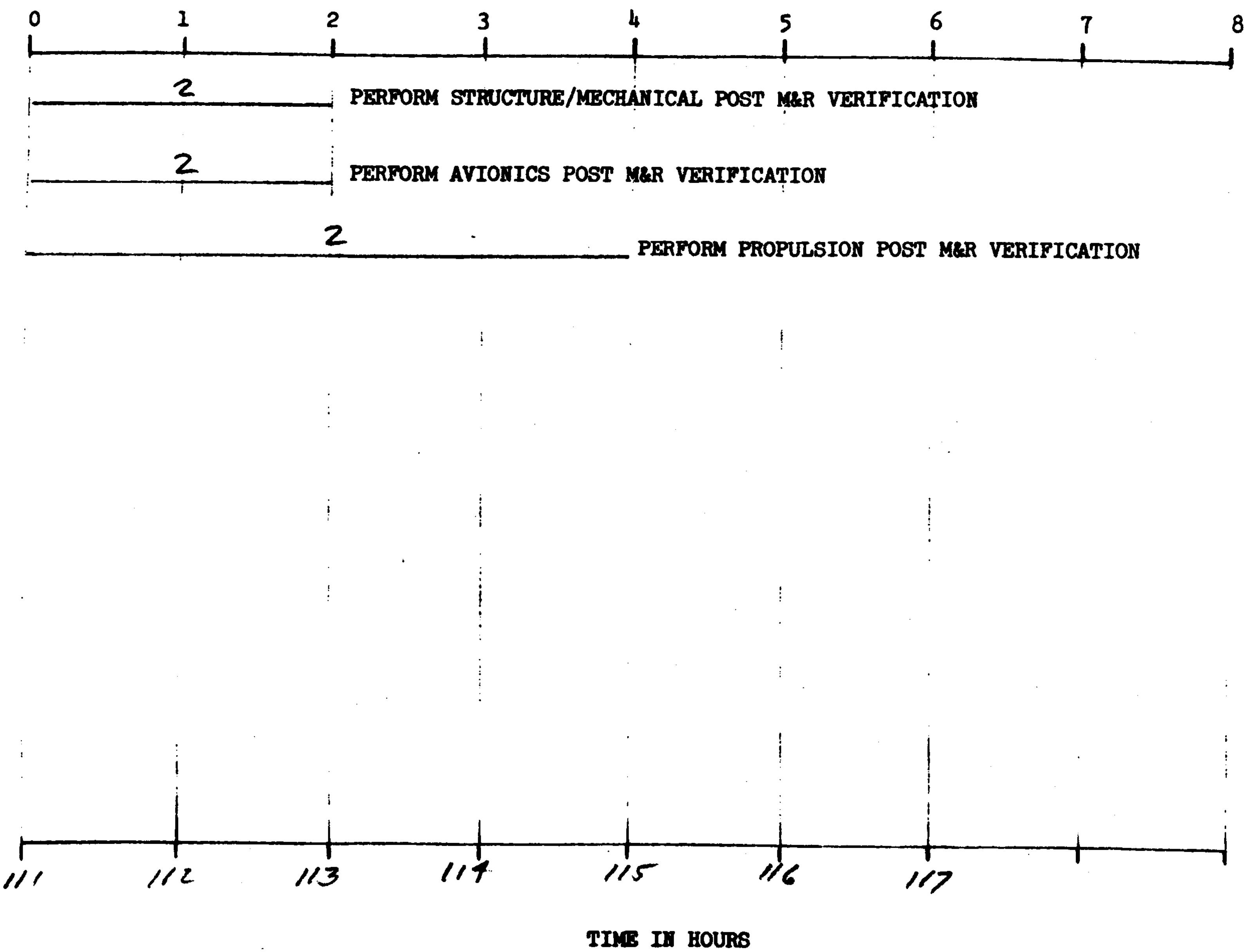


NOTE: THIS ACTIVITY OCCURS AFTER EACH TUG MISSION; HOWEVER, THE MAGNITUDE OF INDIVIDUAL SUBSYSTEM UNSCHEDULED M&R TOGETHER WITH RELATED SKILL REQUIREMENTS WILL VARY.

OPTION NUMBER	3I WTR	FUNCTION TITLE	POST M&R VERIFICATION	FLOW BLOCK NO.	1.2.1



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I WTR	PERFORM POST M&R VERIFICATION - FSE	1.2.2



OPTION NUMBER 3I WTR	FUNCTION TITLE REMOVE M&R GSE	FLOW BLOCK NO. 1.1.14

0 1 2 3 4 5 6 7 8

5 DISCONNECT GSE

4 MOVE GSE AWAY FROM TUG

122 123

TIME IN HOURS

OPTION NUMBER 3I-WTR	FUNCTION TITLE RECEIVE TUG FROM M&R	FLOW BLOCK NO. 2.1.2

0 1 2 3 4 5

2 PREPARE AREA

2 TRANSFER TUG TO WORK STATION

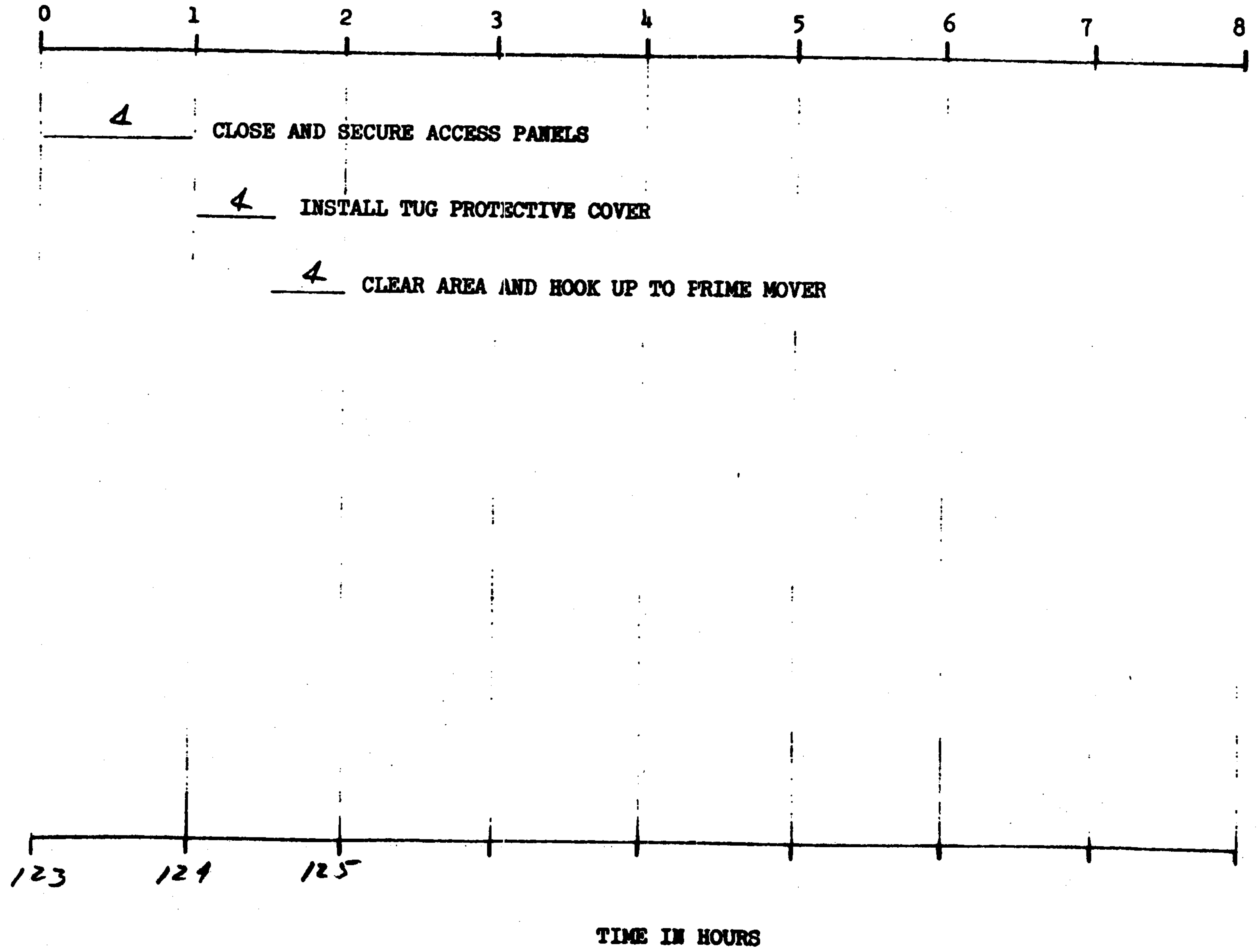
3 POSITION TRANSPORTER

4 INSTALL SIDE WORK STANDS

123 124 125

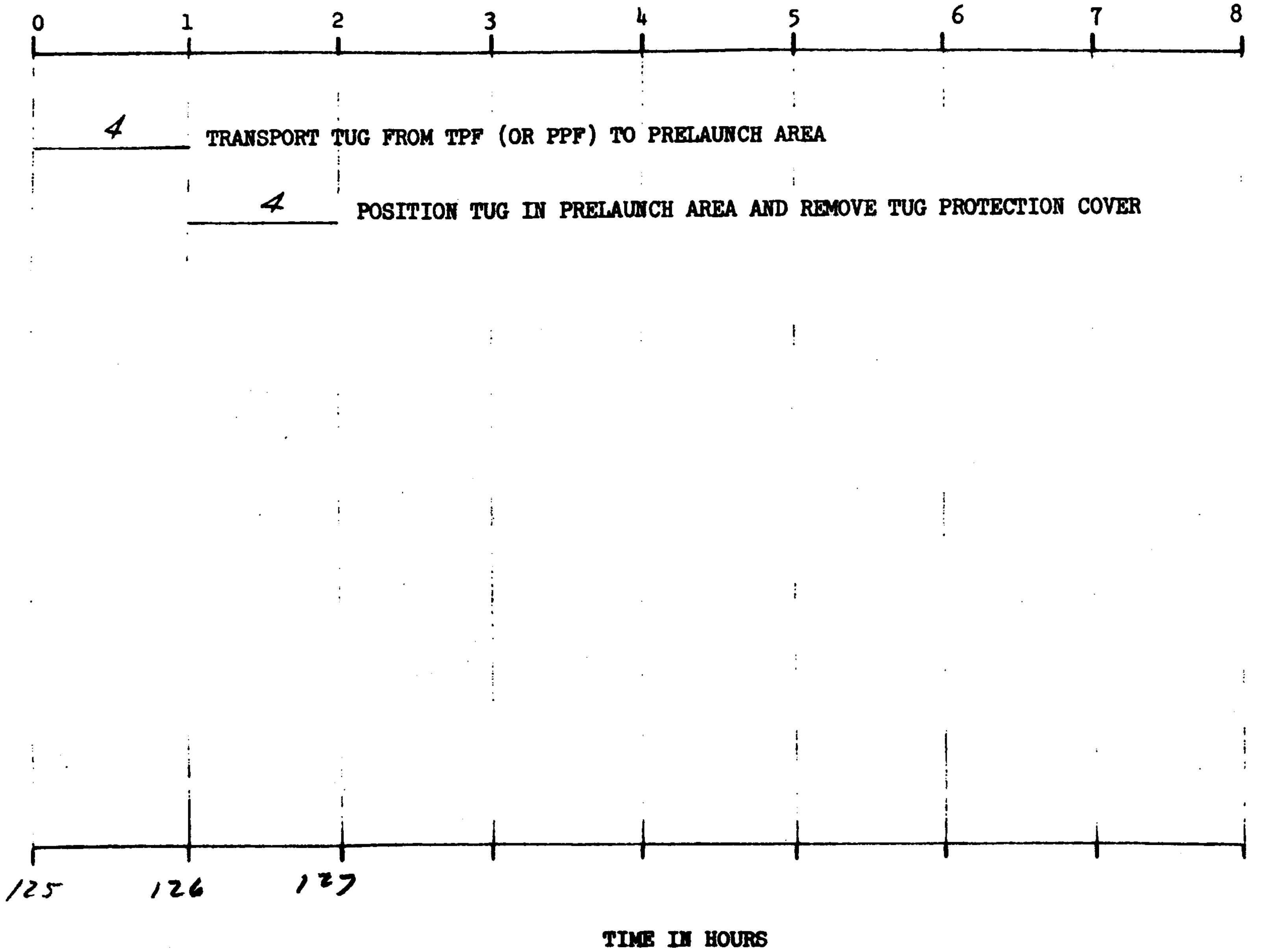
TIME IN HOURS

OPTION NUMBER 3I WTR	FUNCTION TITLE PREPARE FOR TRANSPORT	FLOW BLOCK NO. 1.1.2 1

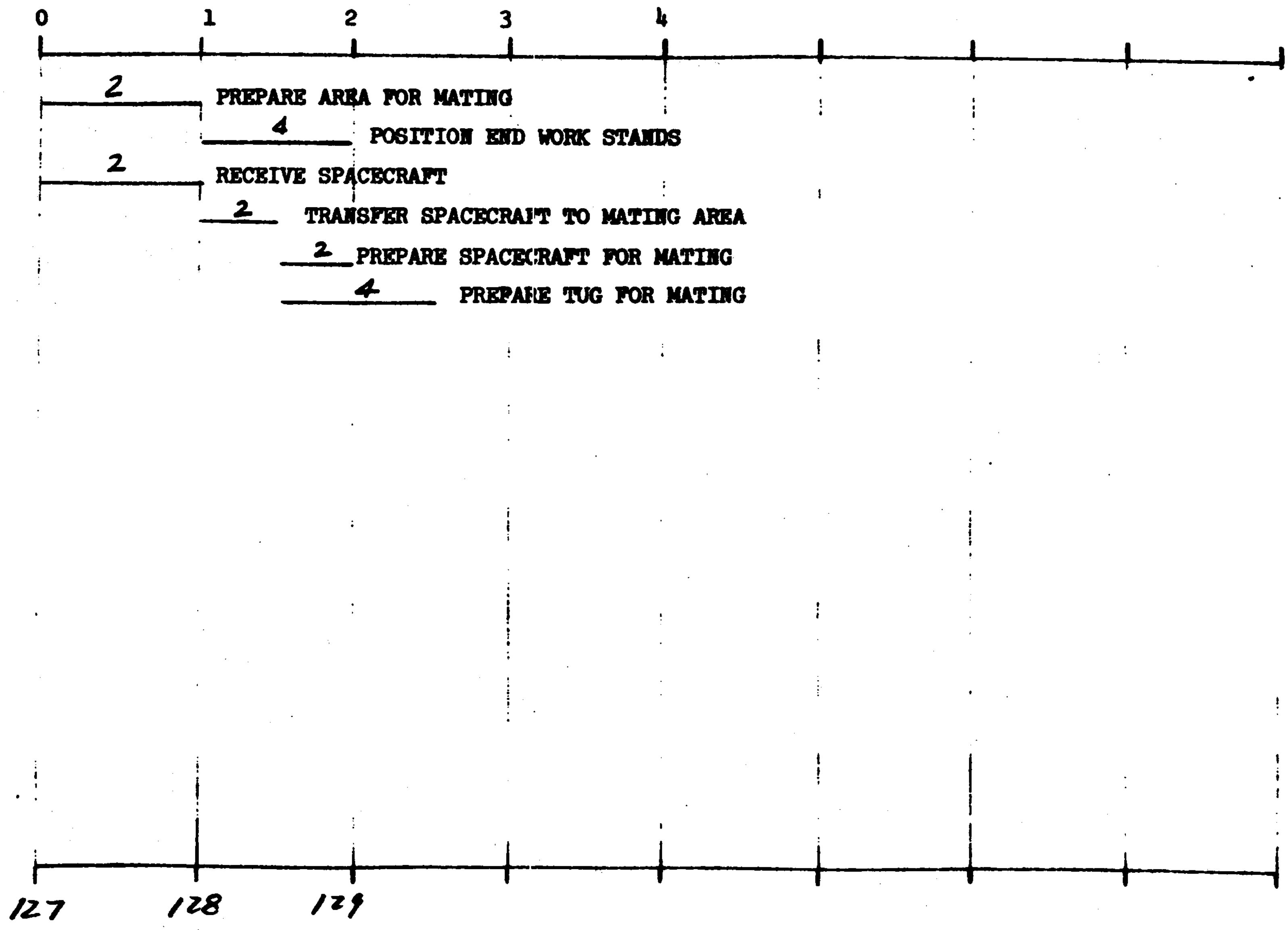


11-91

OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3T- WTR	TRANSFER TO PRELAUNCH	1.1.2 6



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I WTR	PREPARE TUG FOR SPACECRAFT	2.2.2.a



TIME IN HOURS

NOTE: NO KICK STAGE

OPTION NUMBER 3I WTR	FUNCTION TITLE MATE TUG AND SPACECRAFT	FLOW BLOCK NO. 2.2.3

Time scale (hours): 0 1 2 3 4 5 6 7

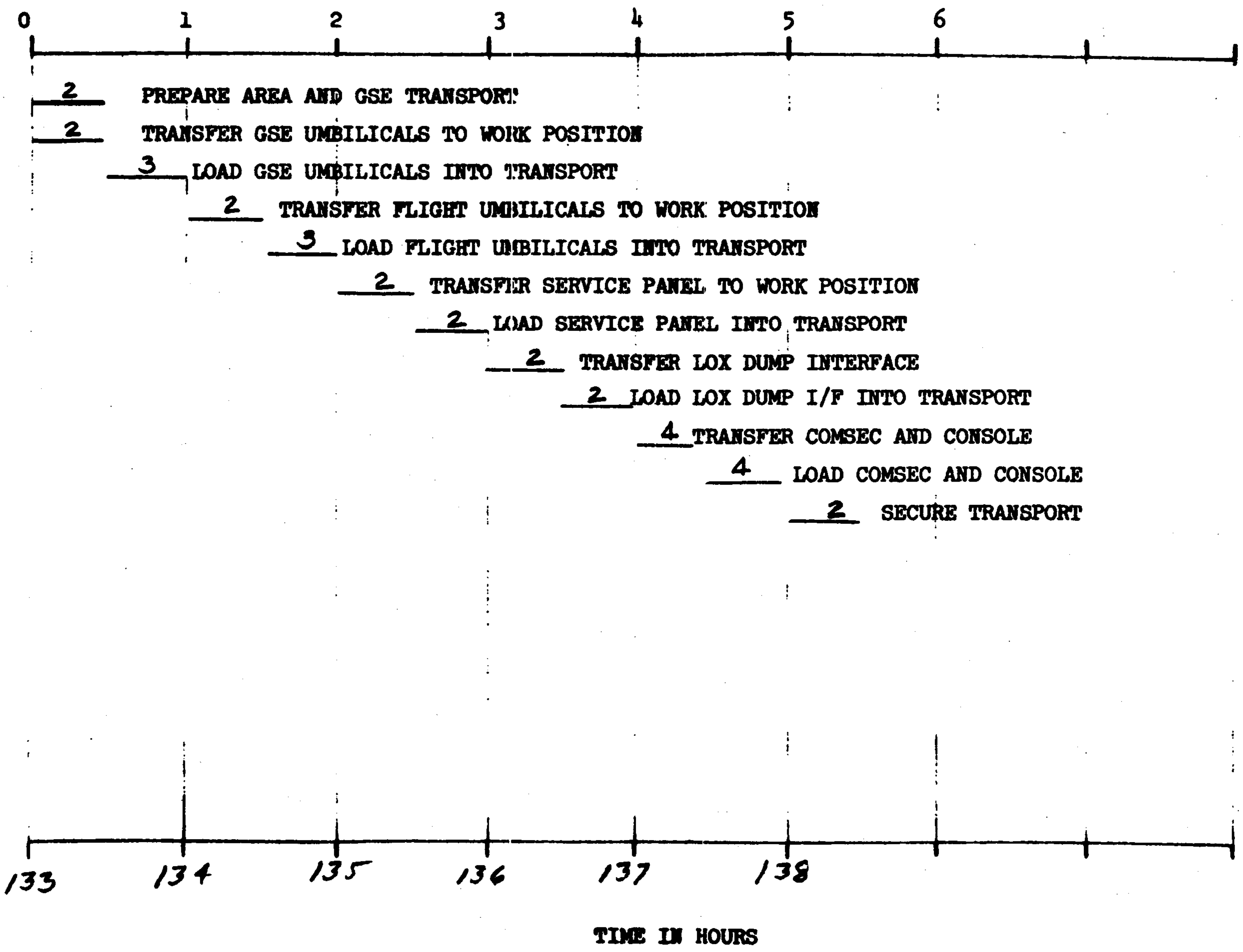
Hours	Task
3	ATTACH SLINGS TO SPACECRAFT
1	POSITION CRANE
3	ATTACH TAG LINES TO SPACECRAFT
4	HOIST SPACECRAFT TO POSITION #1
4	MATE INTERFACES
4	TRANSFER SPACECRAFT TO POSITION #2
4	COMPLETE TUG/SPACECRAFT MATING
3	DETACH SLING AND TAG LINES

NOTE: ADD 3 HRS OF SKILL C FOR DOD MISSIONS

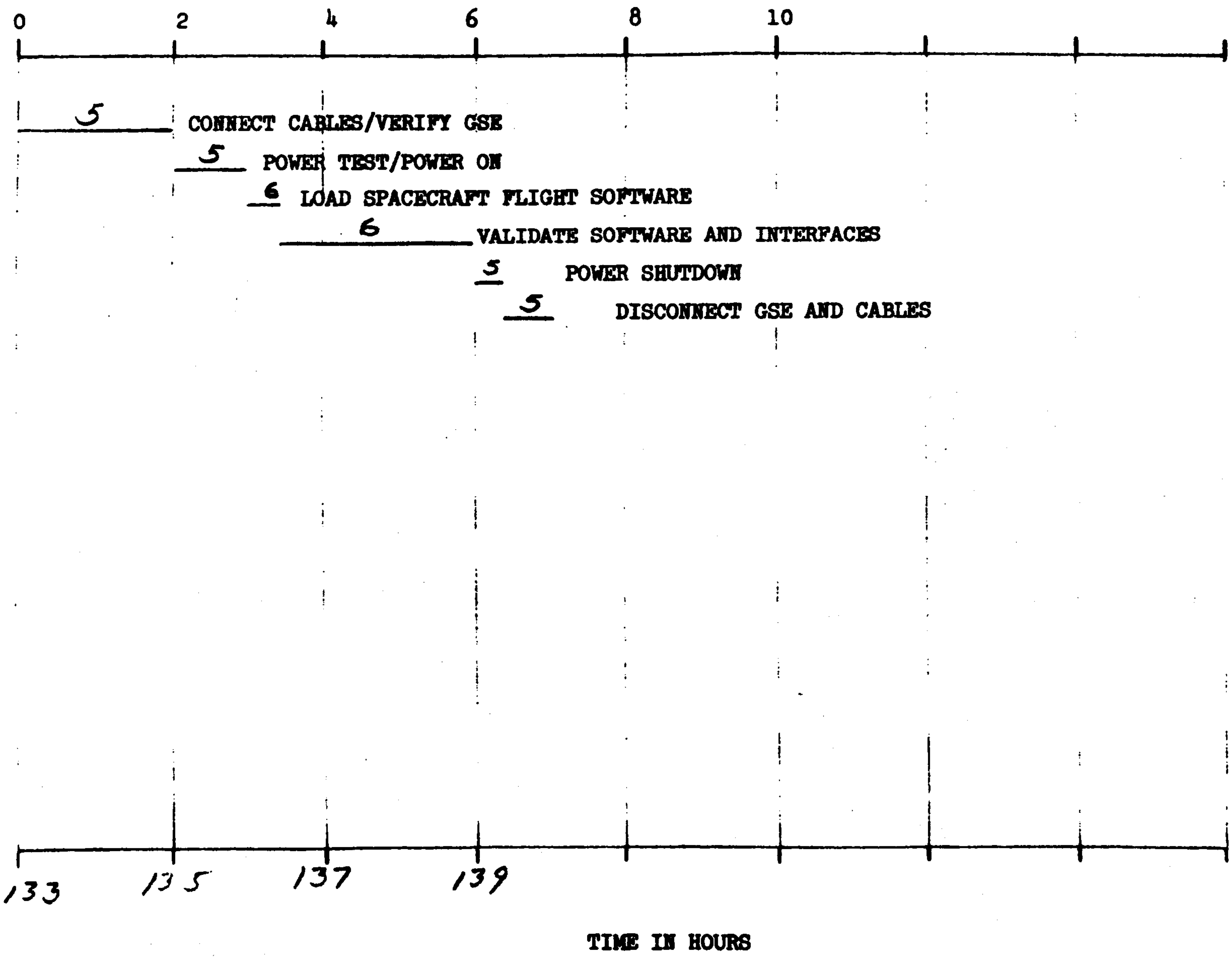
130 131 132 133

TIME IN HOURS

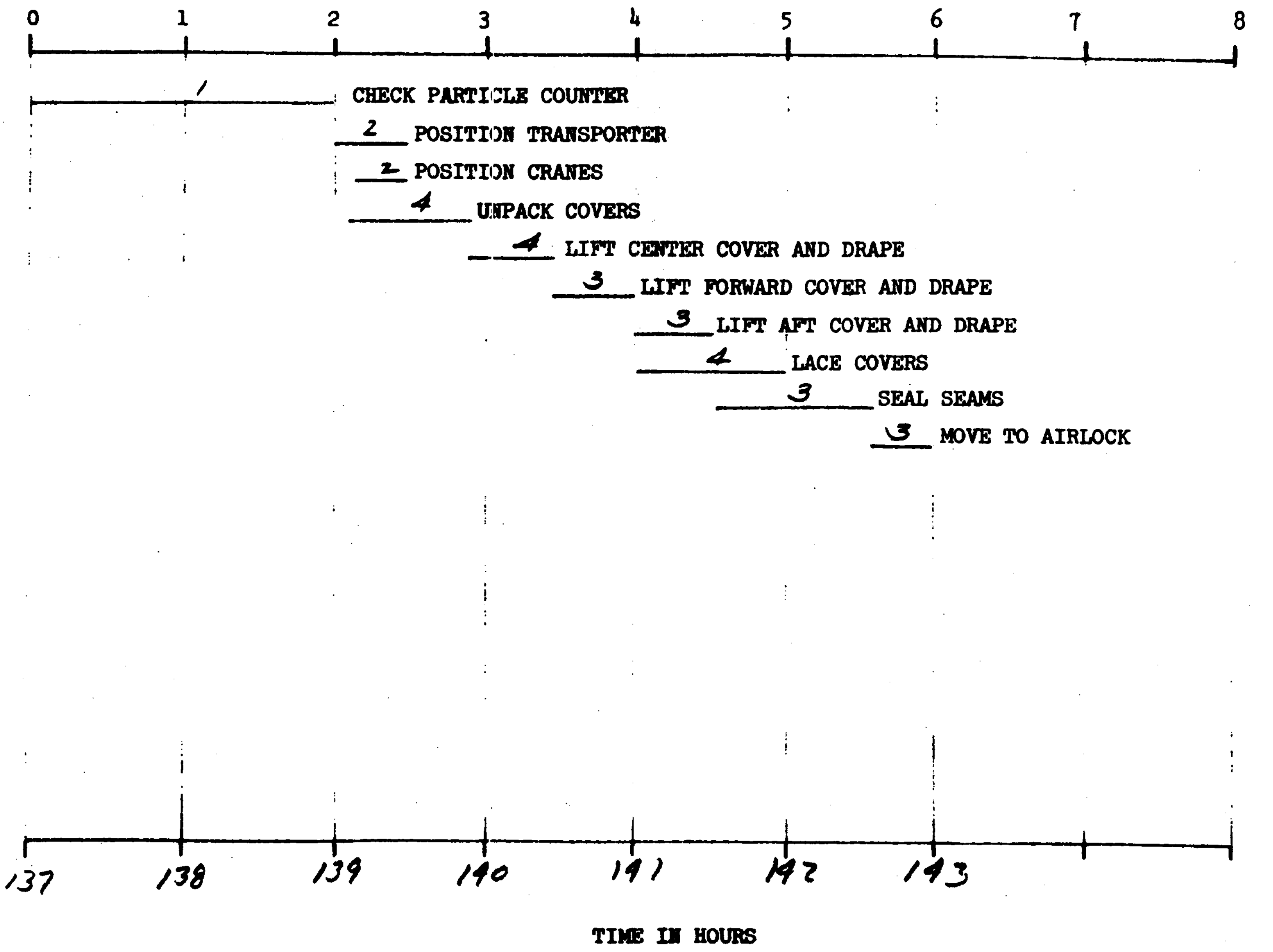
OPTION NUMBER 3I WTR	FUNCTION TITLE RECEIVE FSE FROM M&R	FLOW BLOCK NO. 2.1.1



OPTION NUMBER 3I W/R	FUNCTION TITLE VERIFY TUG-TO-SPACECRAFT INTERFACES	FLOW BLOCK NO. 2.2.4



OPTION NUMBER 3I · WTR	FUNCTION TITLE VERIFY CLEANLINESS	FLOW BLOCK NO. 2.2.5



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I WTR	TRANSFER PAYLOAD TO SPF	2.1.5

0 1 2 3 4 5 6 7

2 MATE PURGE INTERFACE AND VERIFY

1 INITIATE PURGE

2 ATTACH TRACTOR AND CLEAR AREA

2 TRANSFER TO SPF

2 POSITION TRANSPORTER

4 POSITION CLEANLINESS TENT

2 INITIATE FLOW

4 REMOVE AFT COVER

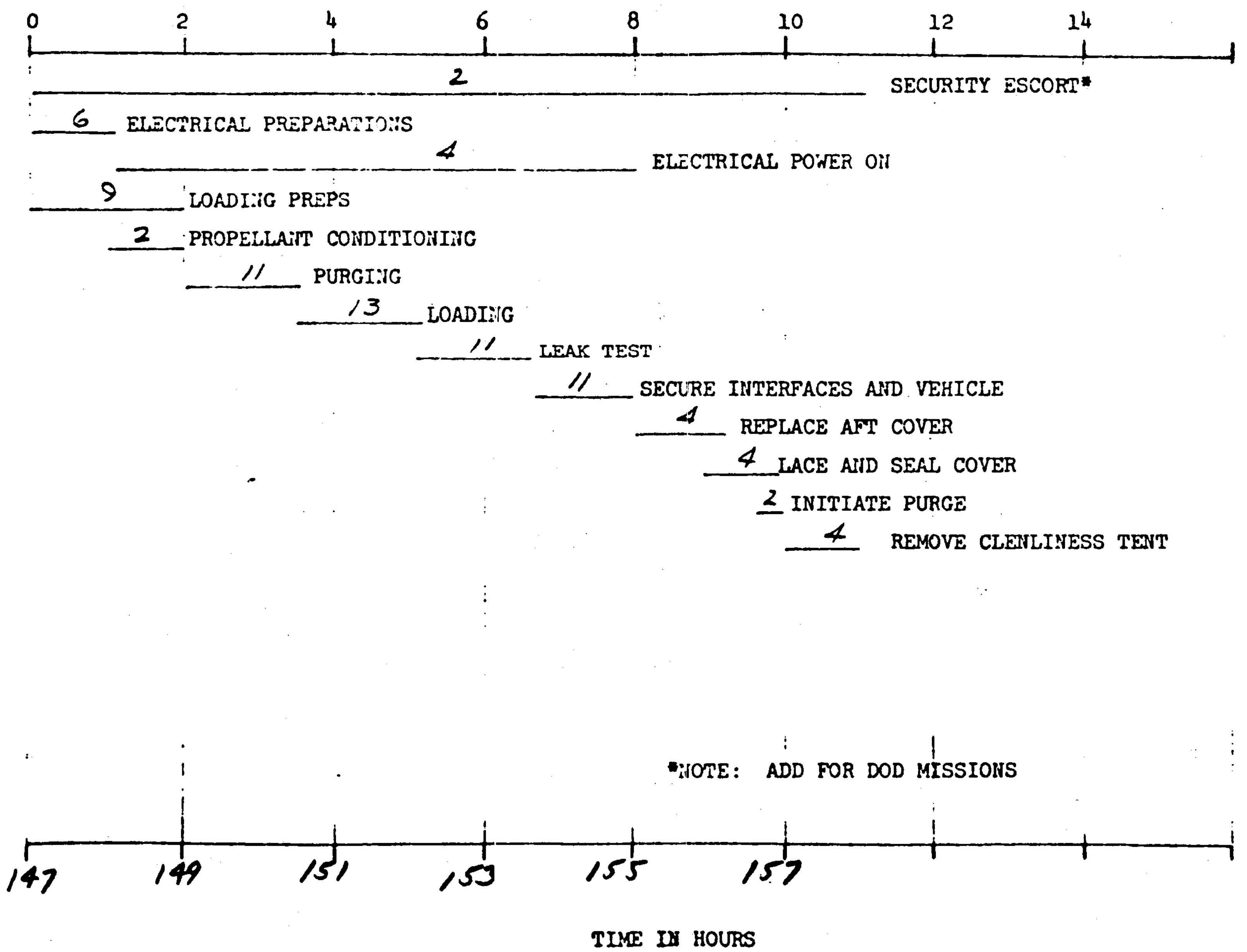
2 SECURITY ESCORT*

*NOTE: ADD FOR DOD MISSIONS

143 144 145 146 147

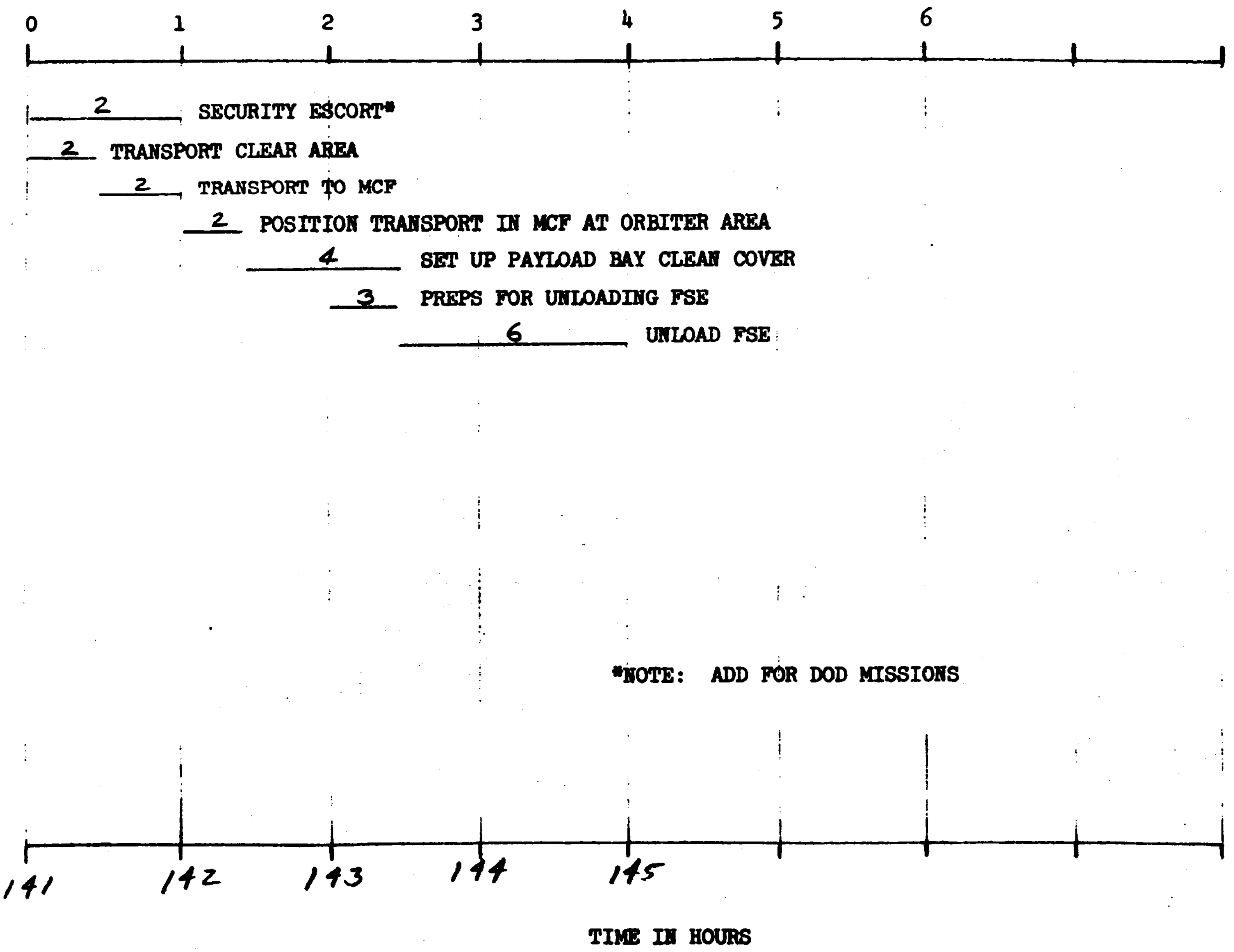
TIME IN HOURS

OPTION NUMBER 3I WTR	FUNCTION TITLE STORABLE PROPELLANT SERVICING	FLOW BLOCK NO. 2.1.7

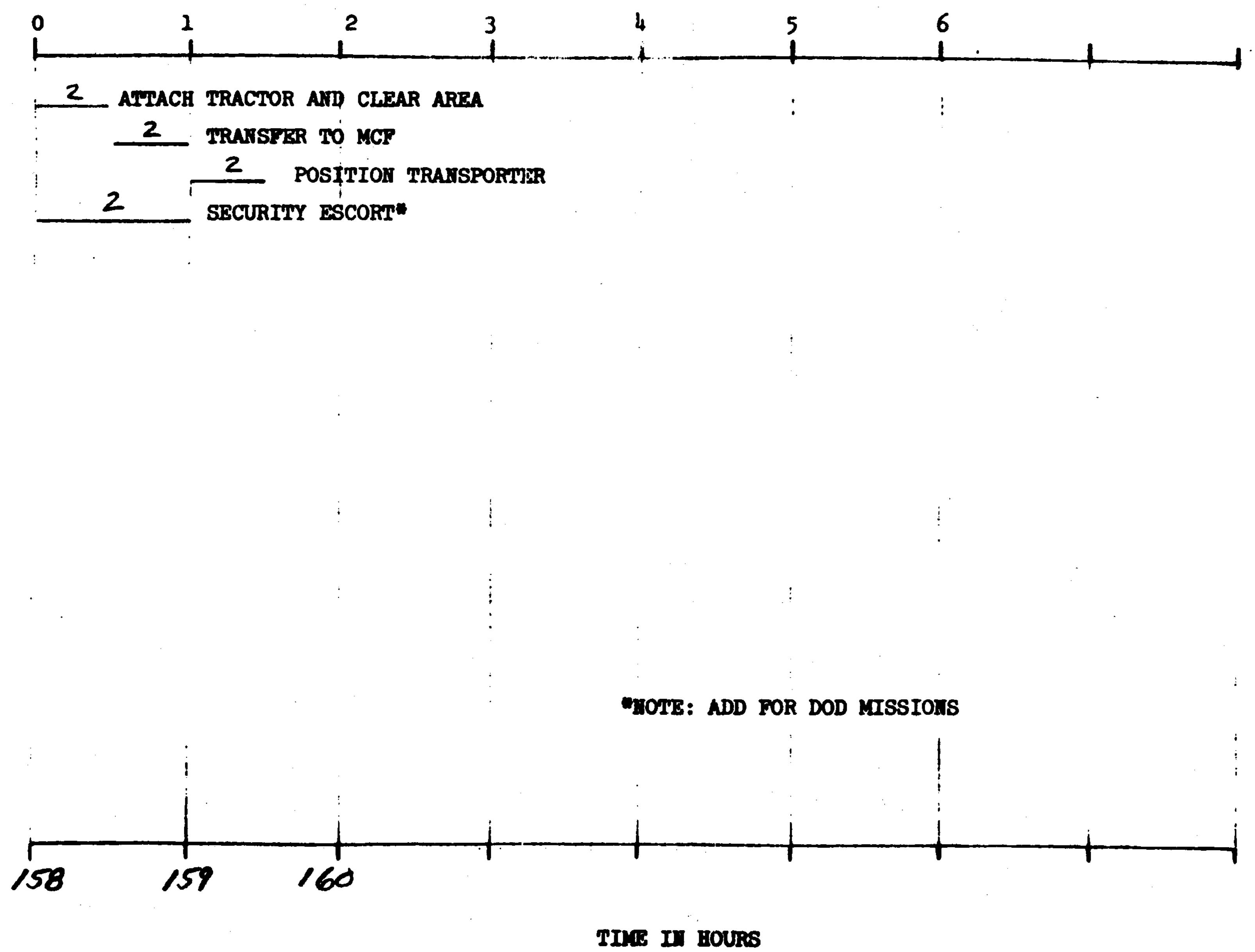


NOTE: MONOPROPELLANT AT SPF

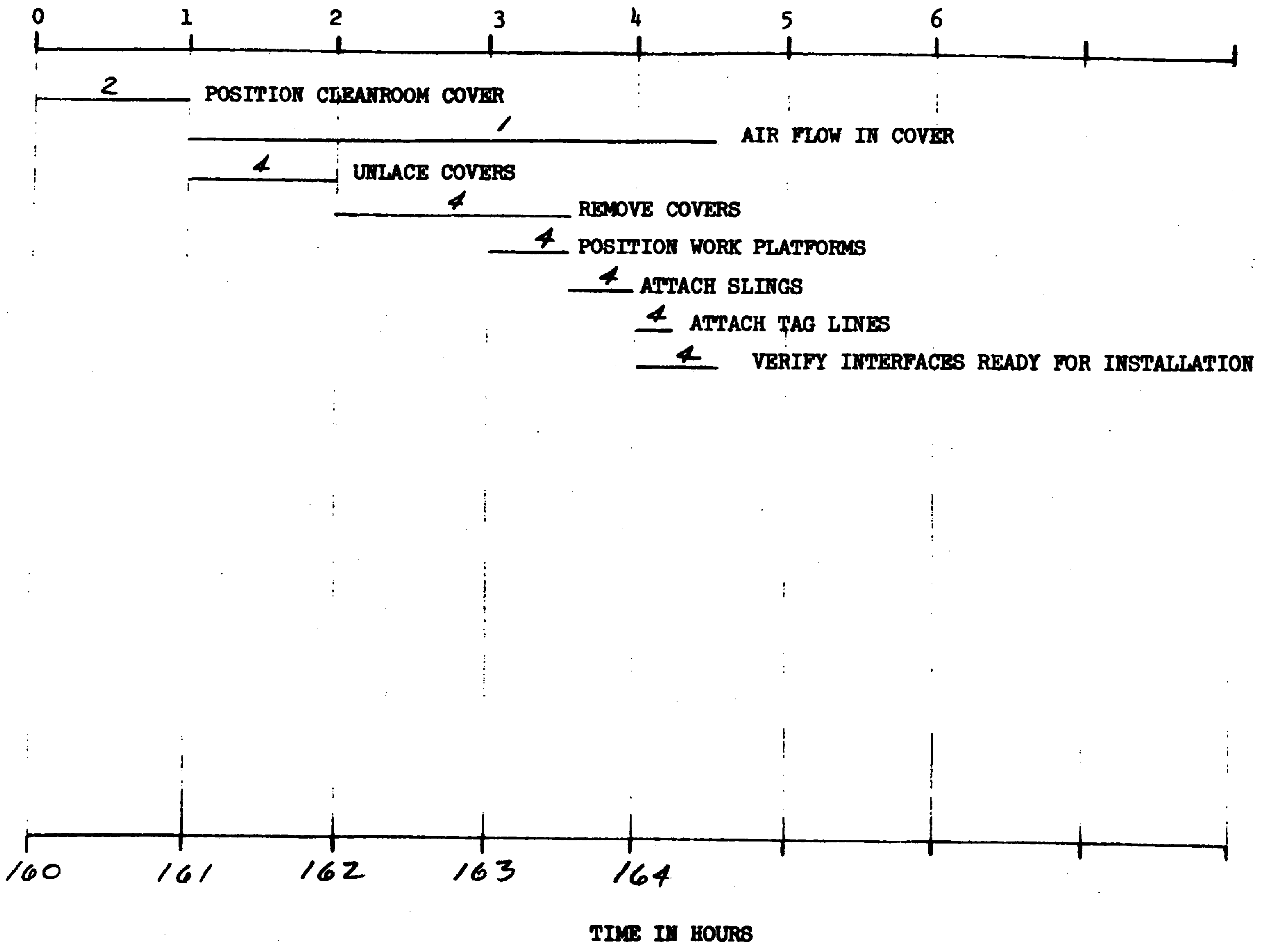
OPTION NUMBER 3I WTR	FUNCTION TITLE TRANSFER FSE TO MCF	FLOW BLOCK NO. 2.3.1



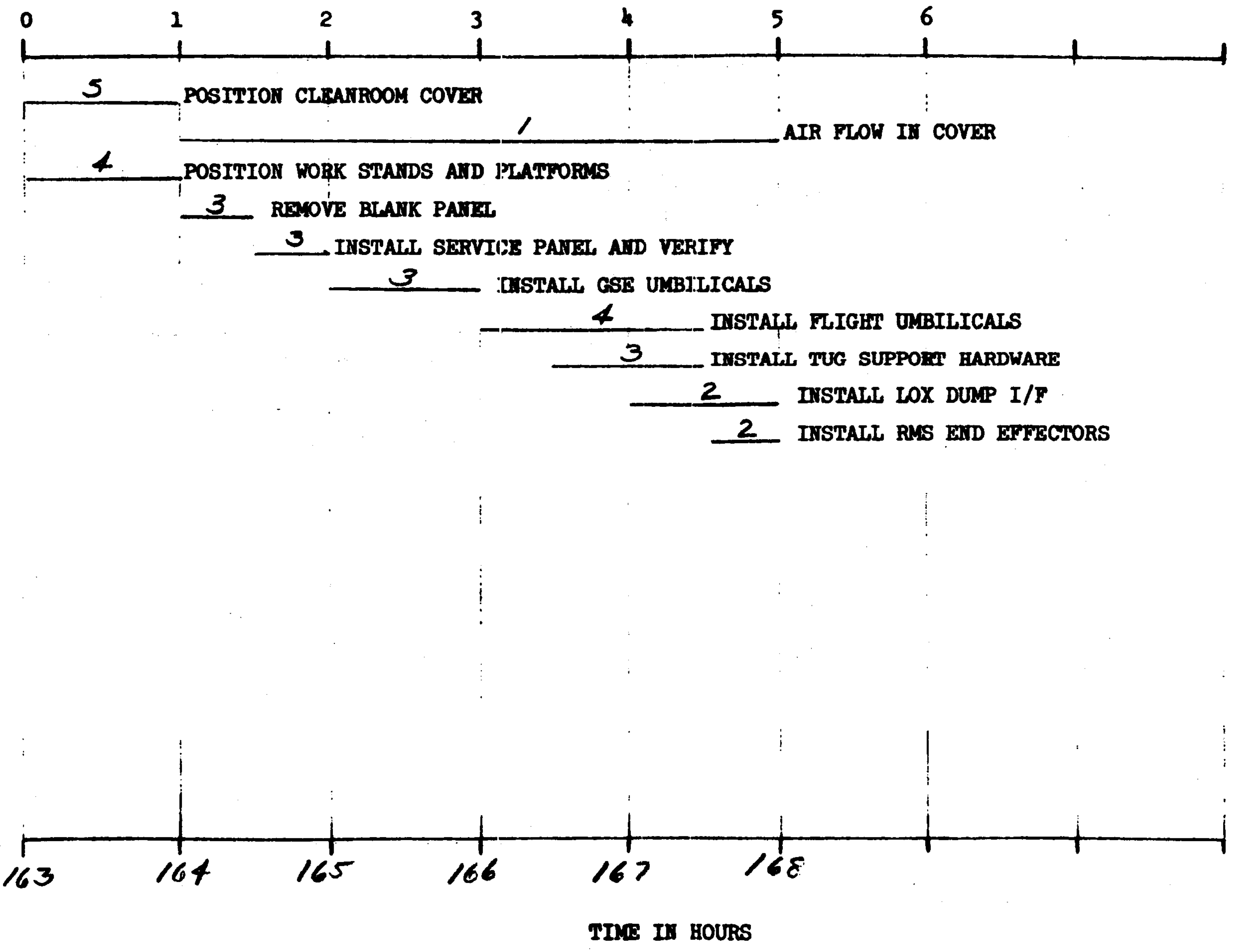
OPTION NUMBER 3I WTR	FUNCTION TITLE TRANSFER PAYLOAD TO MCF	FLOW BLOCK NO. 2.3.4



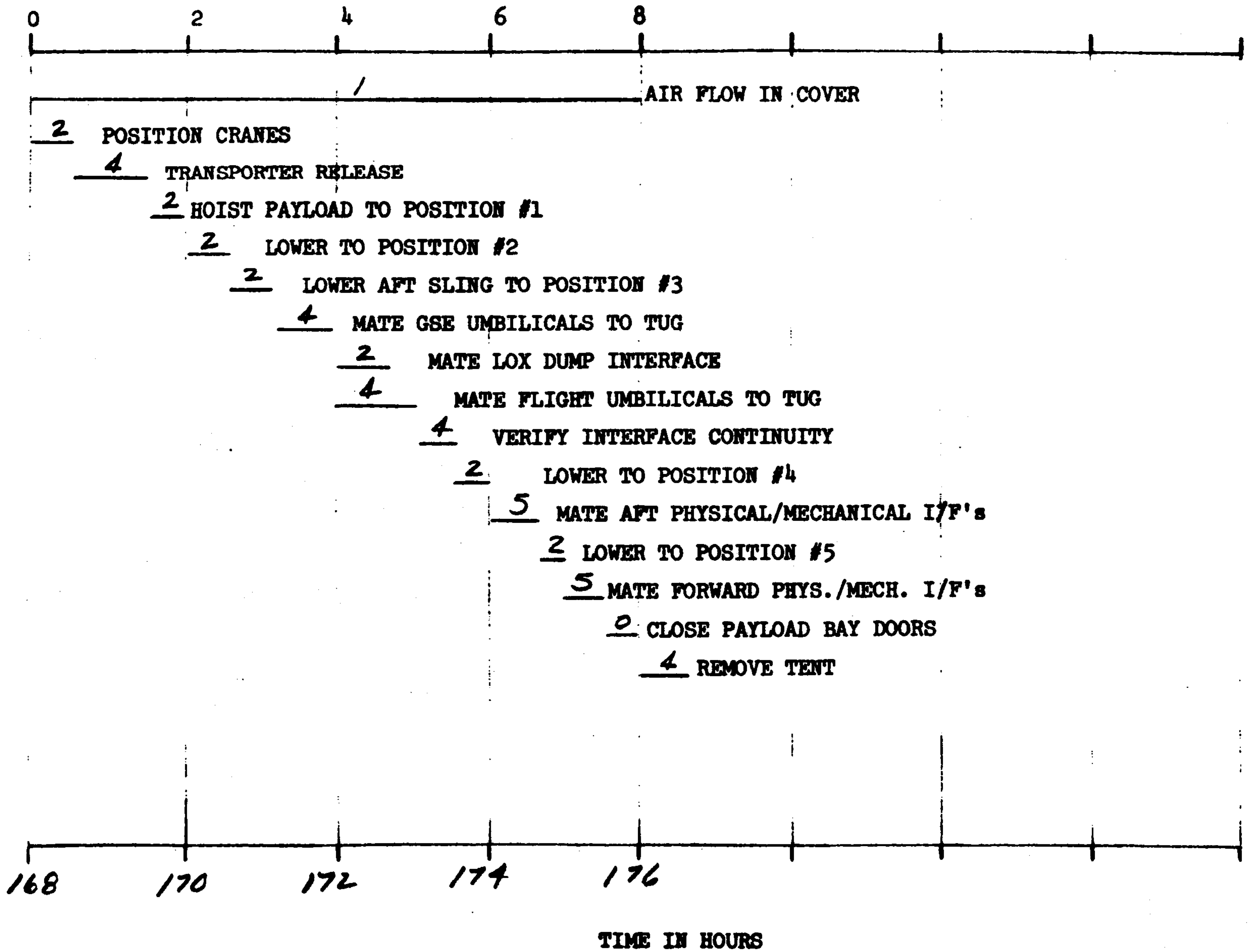
OPTION NUMBER 3I WTR	FUNCTION TITLE PAYLOAD INSTALLATION PREPS	FLOW BLOCK NO. 2.3.6



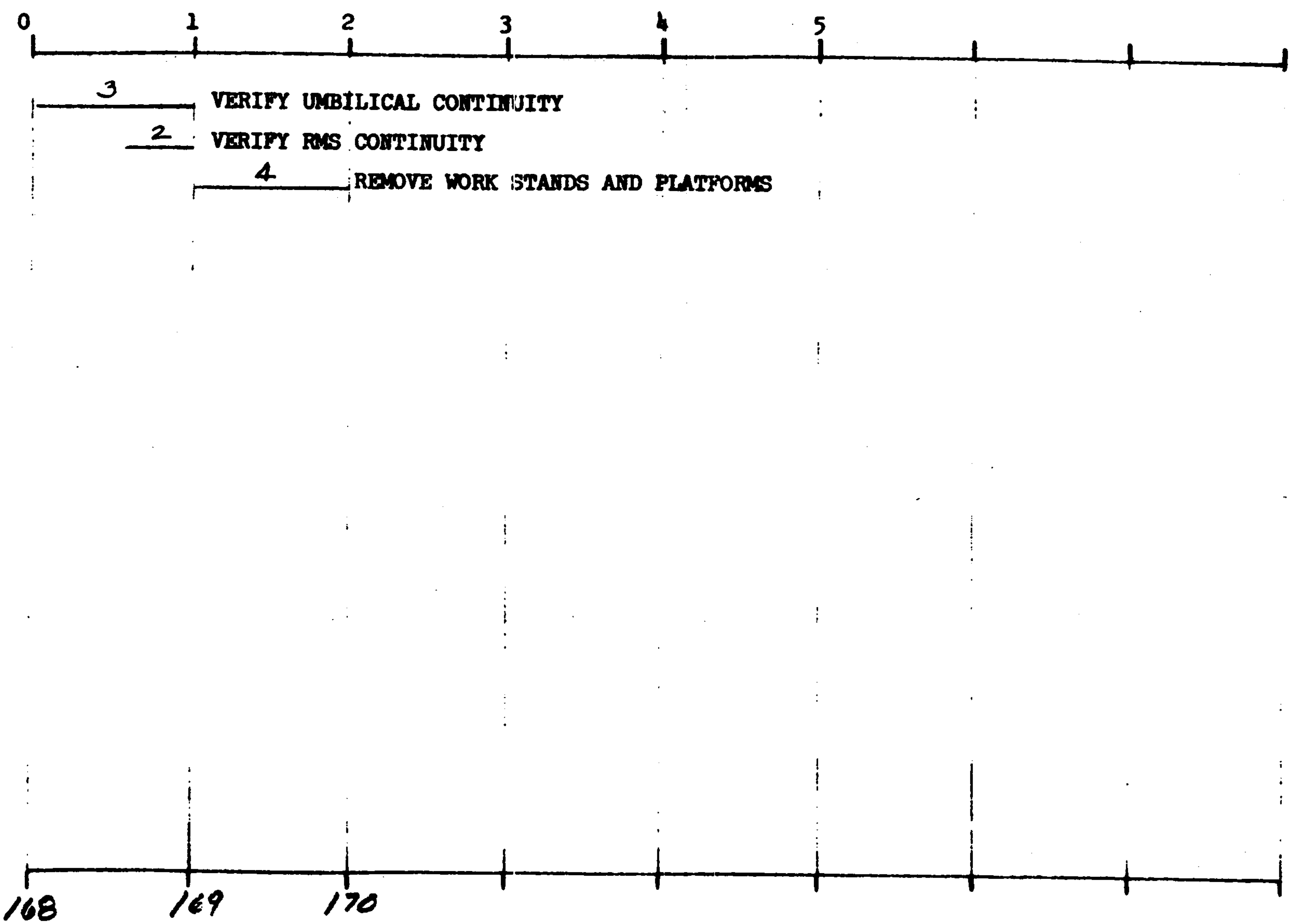
OPTION NUMBER 3I WTR	FUNCTION TITLE INSTALL FSE IN PAYLOAD BAY	FLOW BLOCK NO. 2.3.2.2



OPTION NUMBER 3I WTR	FUNCTION TITLE PAYLOAD INSTALLATION MCF	FLOW BLOCK NO. 2.3.7

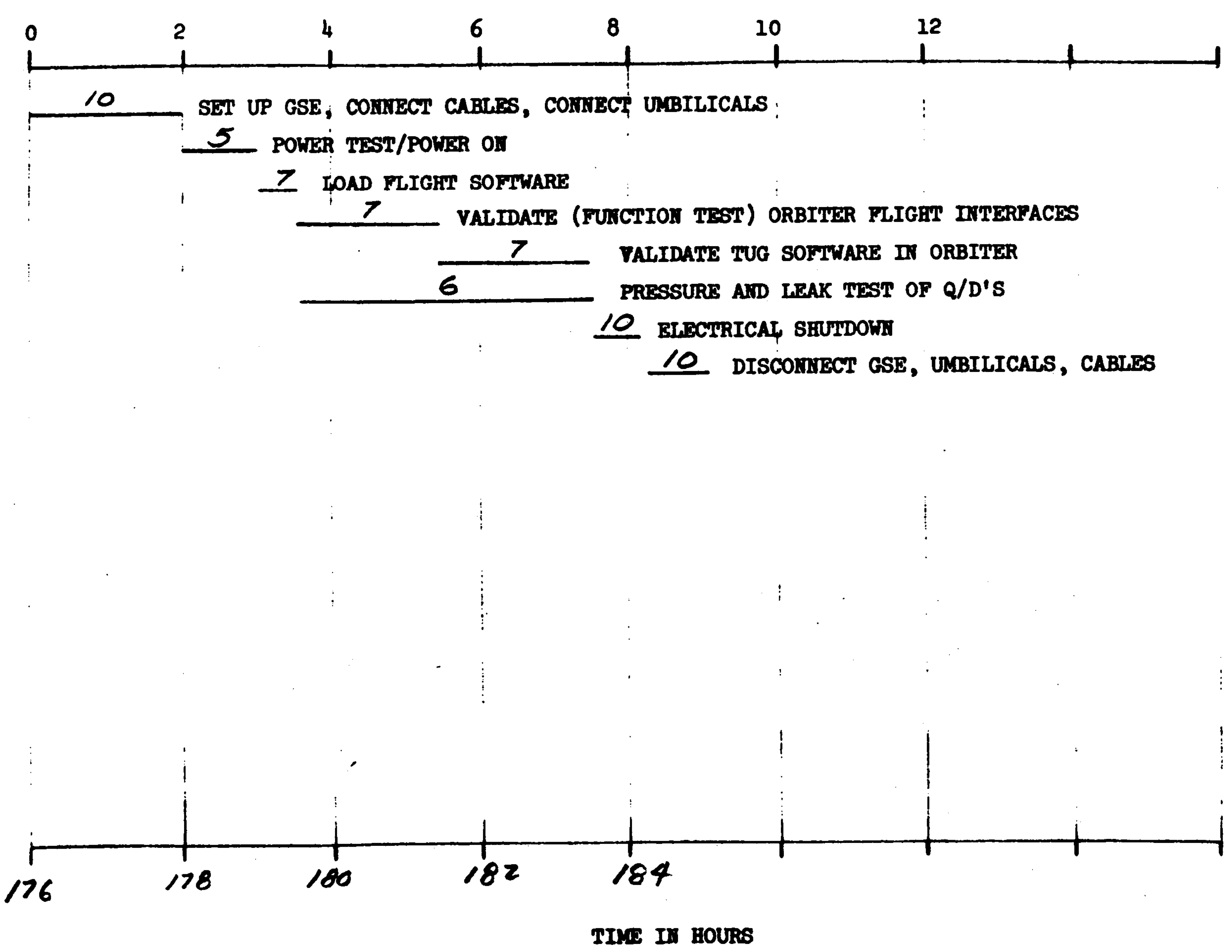


OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I WTR	VERIFY PSE INTERFACES	2.3.3

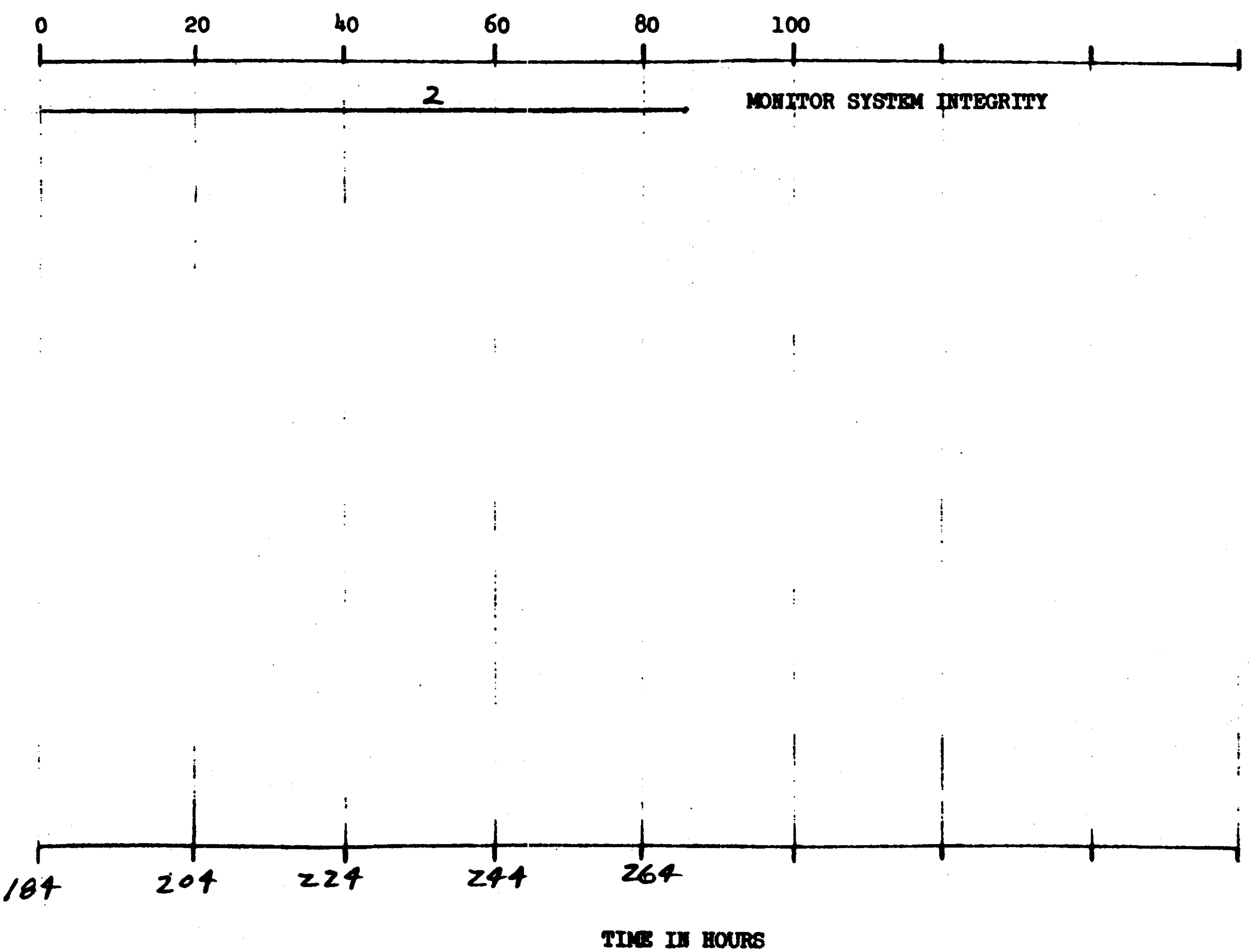


TIME IN HOURS

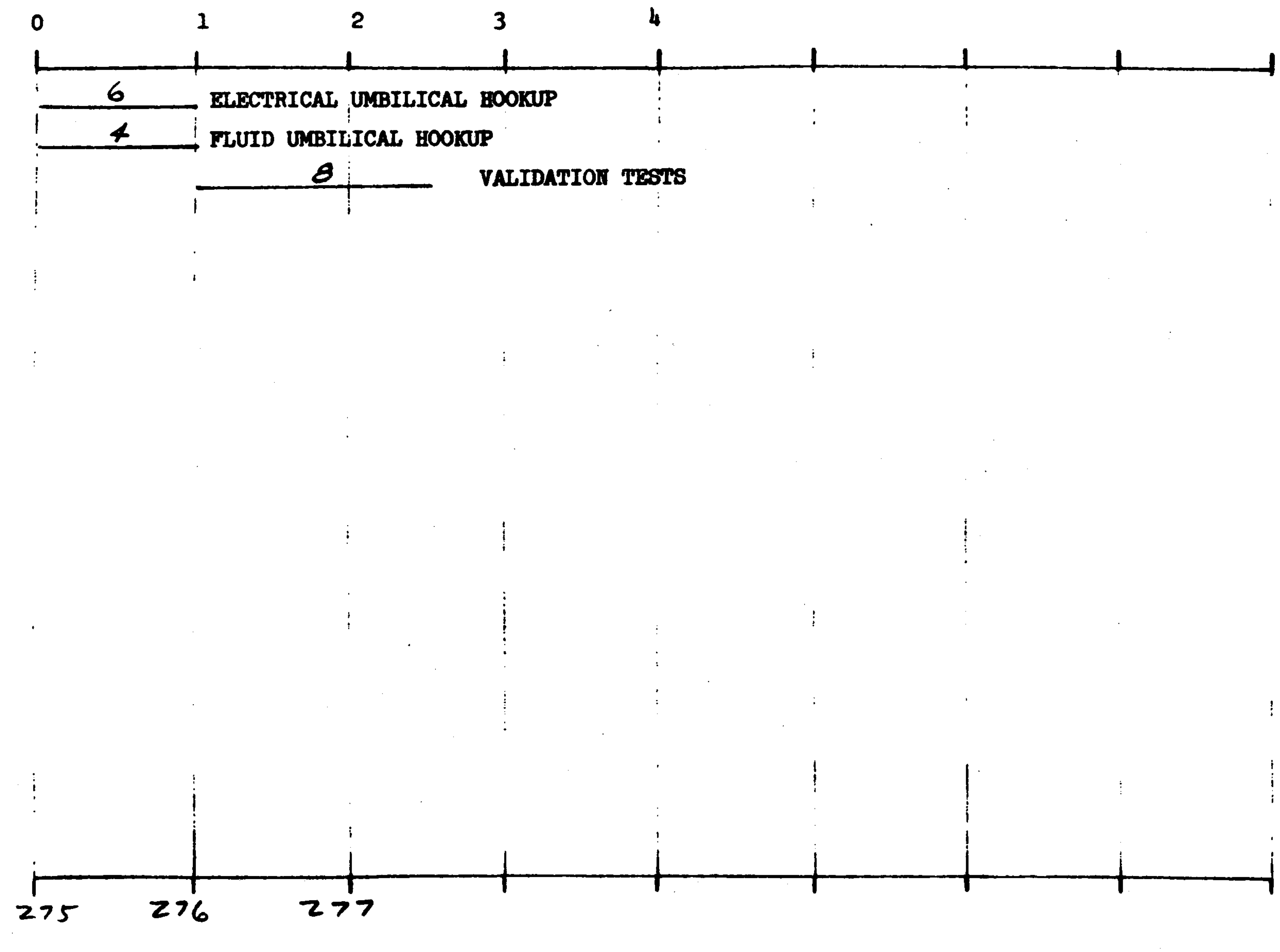
OPTION NUMBER 3I WTR	FUNCTION TITLE VERIFY PAYLOAD-TO-SHUTTLE INTERFACES	FLOW BLOCK NO. 2.3.9



OPTION NUMBER 3I WTR	FUNCTION TITLE MONITOR STORABLE ACPS	FLOW BLOCK NO. 2.4.1.a

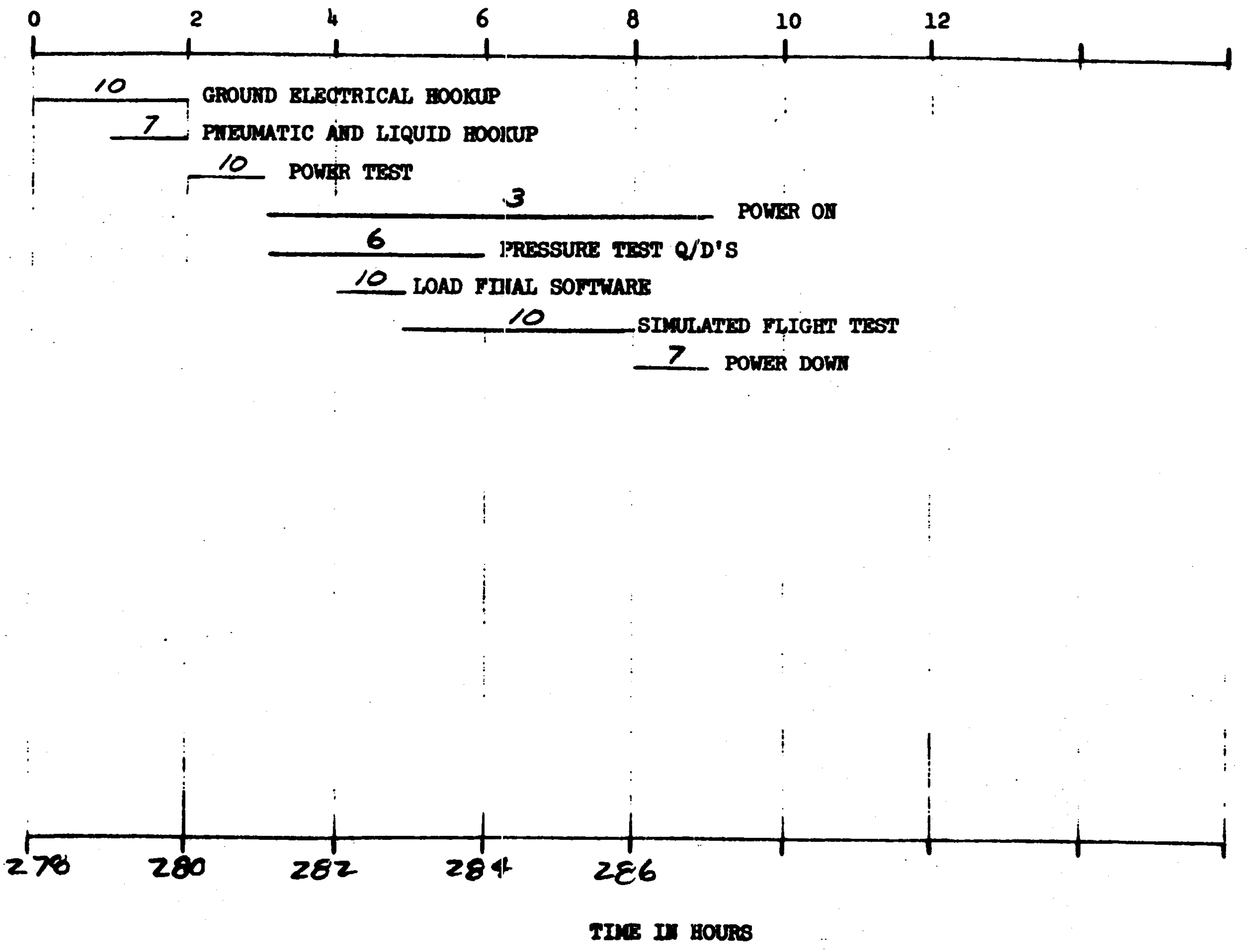


OPTION NUMBER 3I WTR	FUNCTION TITLE TUG SERVICE AT PAD (NON-CRYOS)	FLOW BLOCK NO. 2.4.2.a

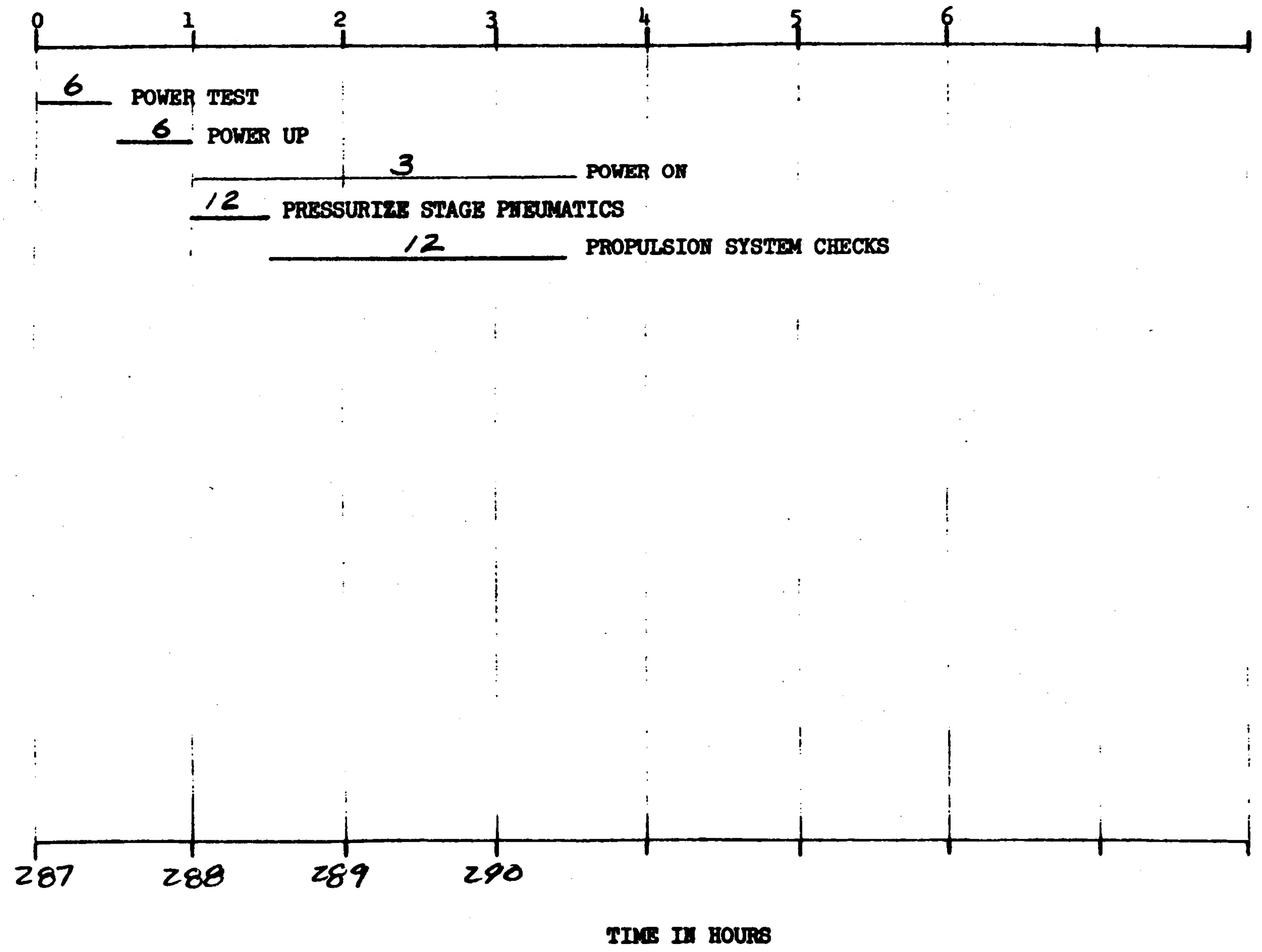


UMBILICAL HOOKUP

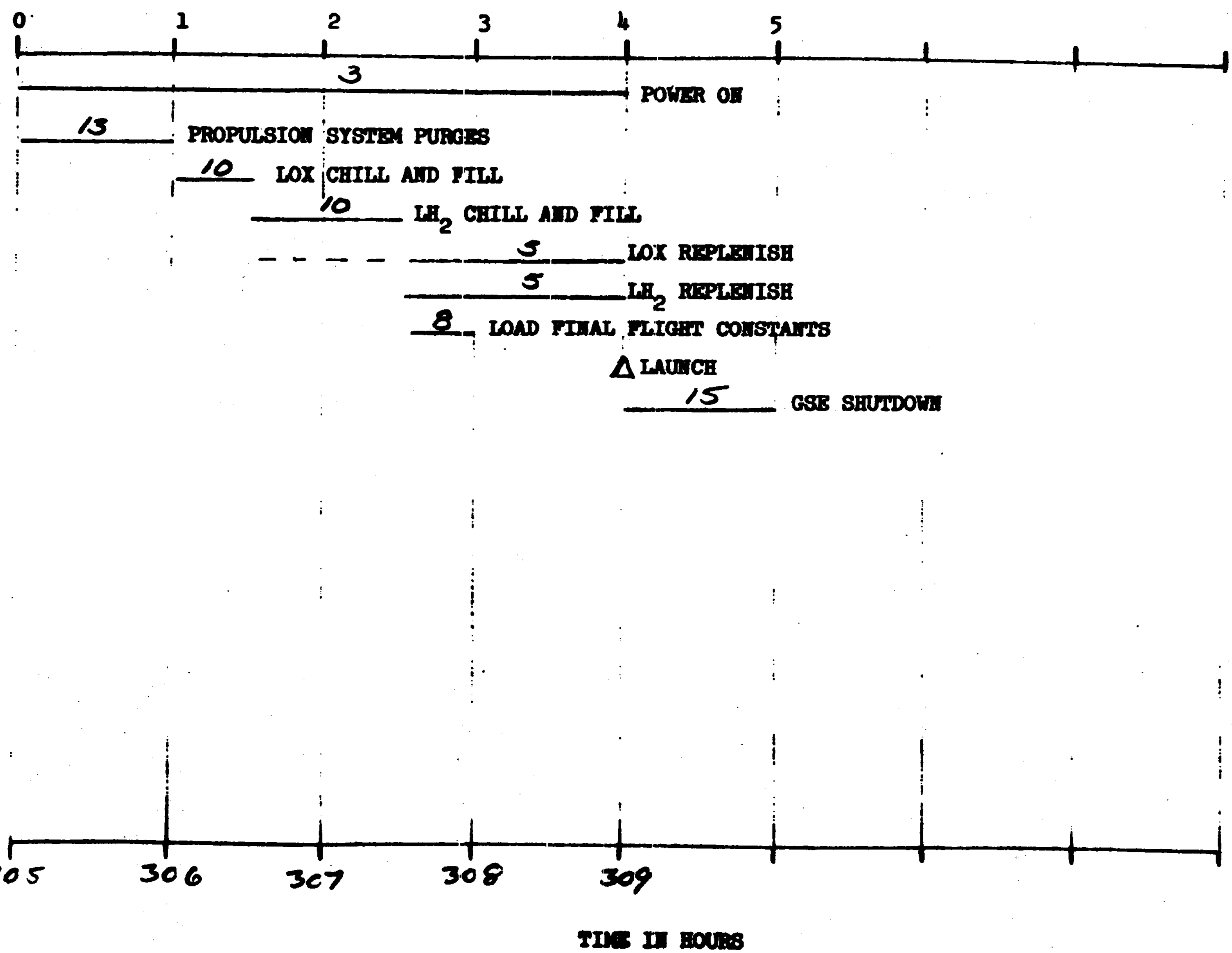
OPTION NUMBER 3I WTR	FUNCTION TITLE ORBITER/PAYLOAD INTEGRATION SYSTEM TEST	FLOW BLOCK NO. 2.4.1



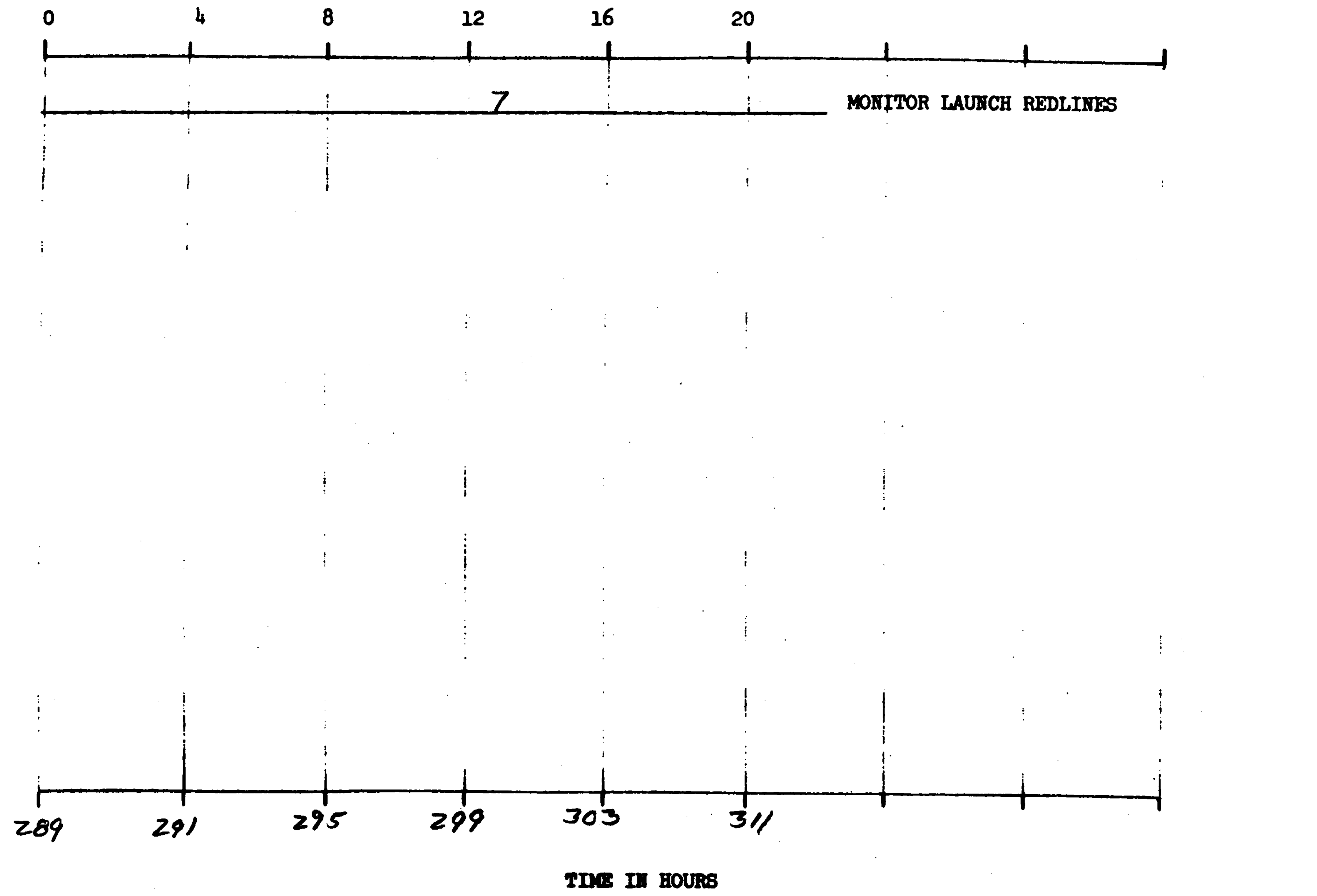
OPTION NUMBER 3I WTR	FUNCTION TITLE TUG SERVICE AT PAD (NON-CRYO)	FLOW BLOCK NO. 2.4.2.b



OPTION NUMBER 3I WTR	FUNCTION TITLE TUG SERVICE AT PAD (CRYO'S)	FLOW BLOCK NO. 2.4.3



OPTION NUMBER 3I WTR	FUNCTION TITLE SUBSYSTEM MONITORING AT PAD	FLOW BLOCK NO. 2.4.4



TASK TIMELINES

FOR

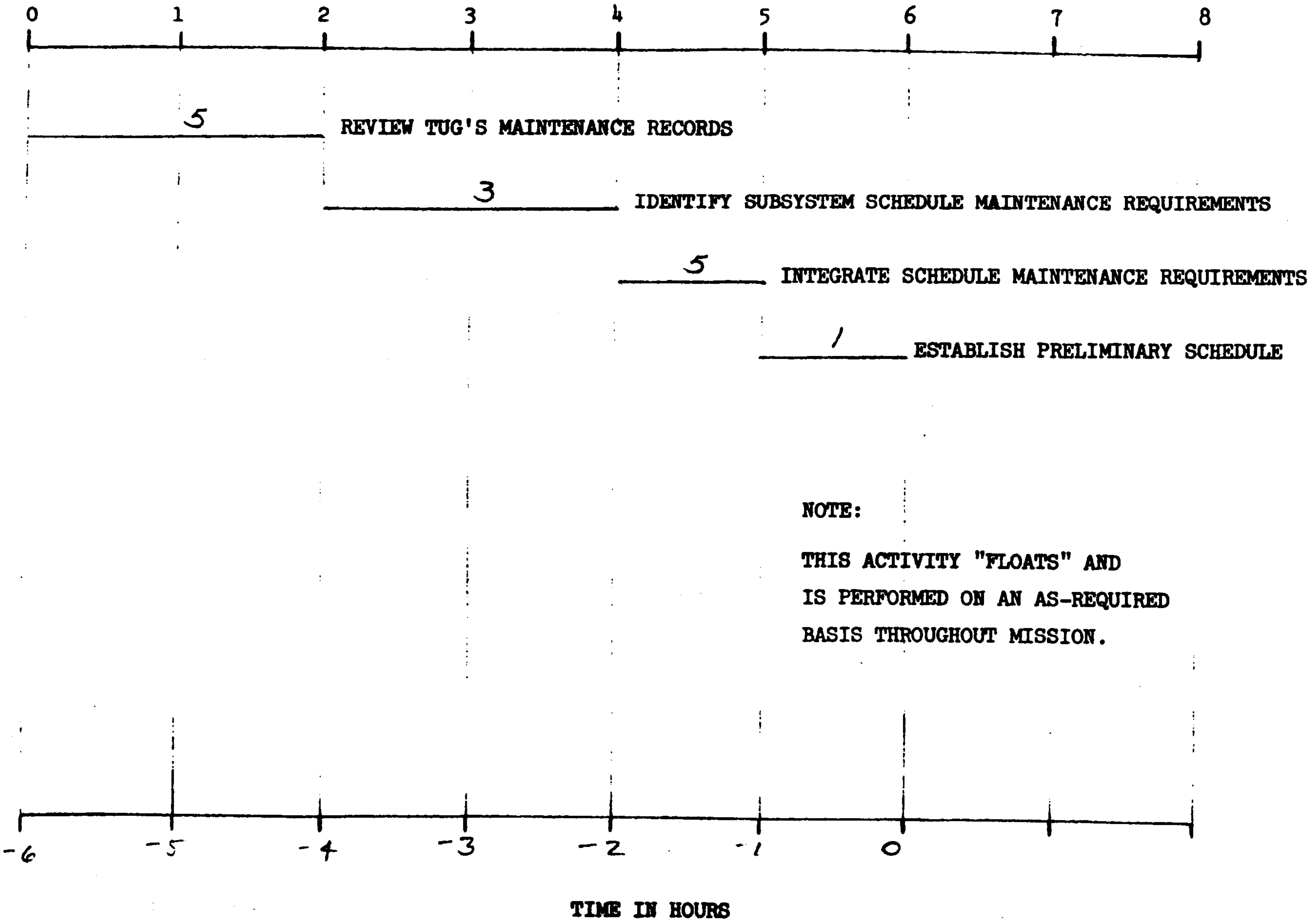
THE CRYOGENIC TUG

GROUND AND LAUNCH OPERATIONS

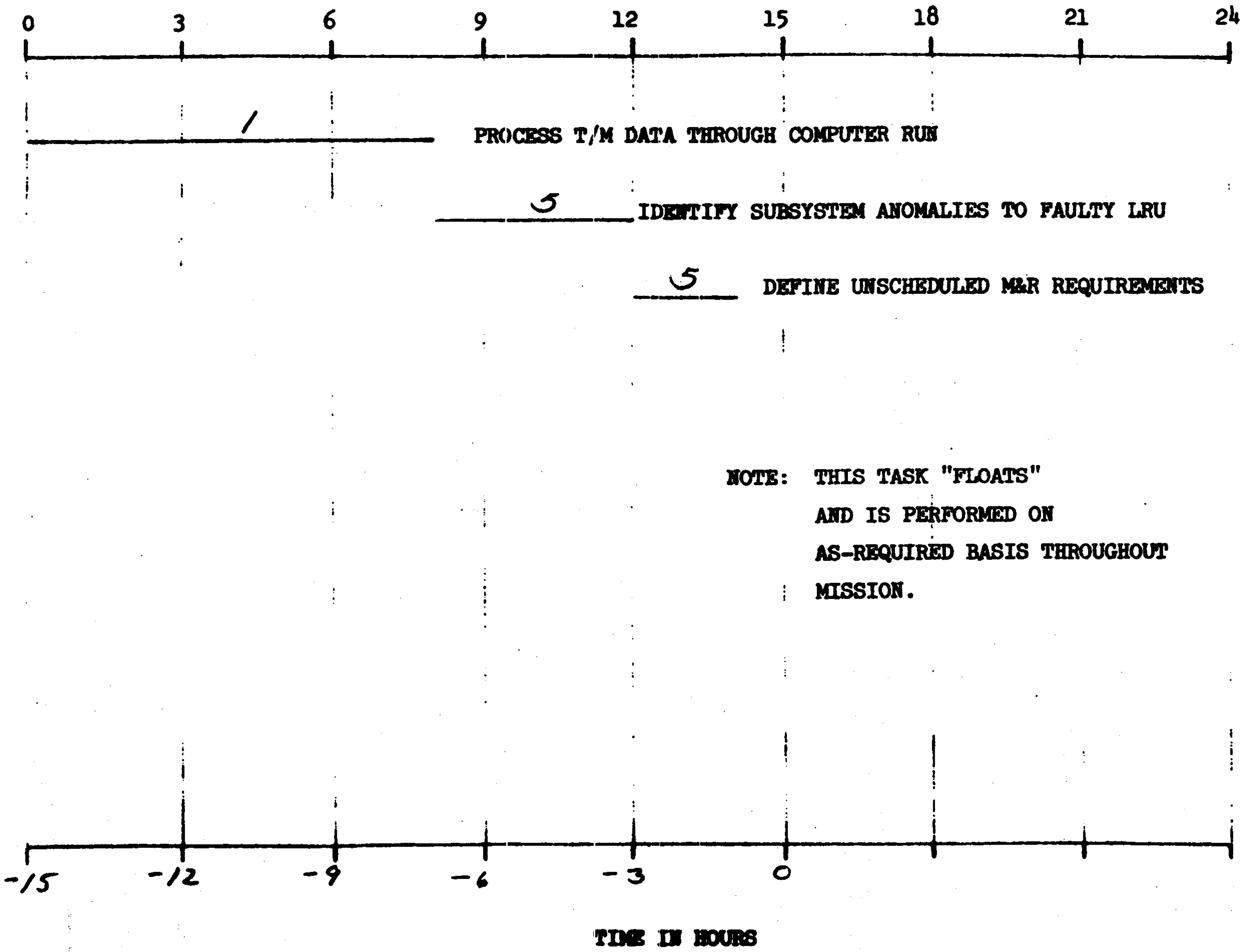
OPTION NO. 3F WTR

SEPTEMBER 1973

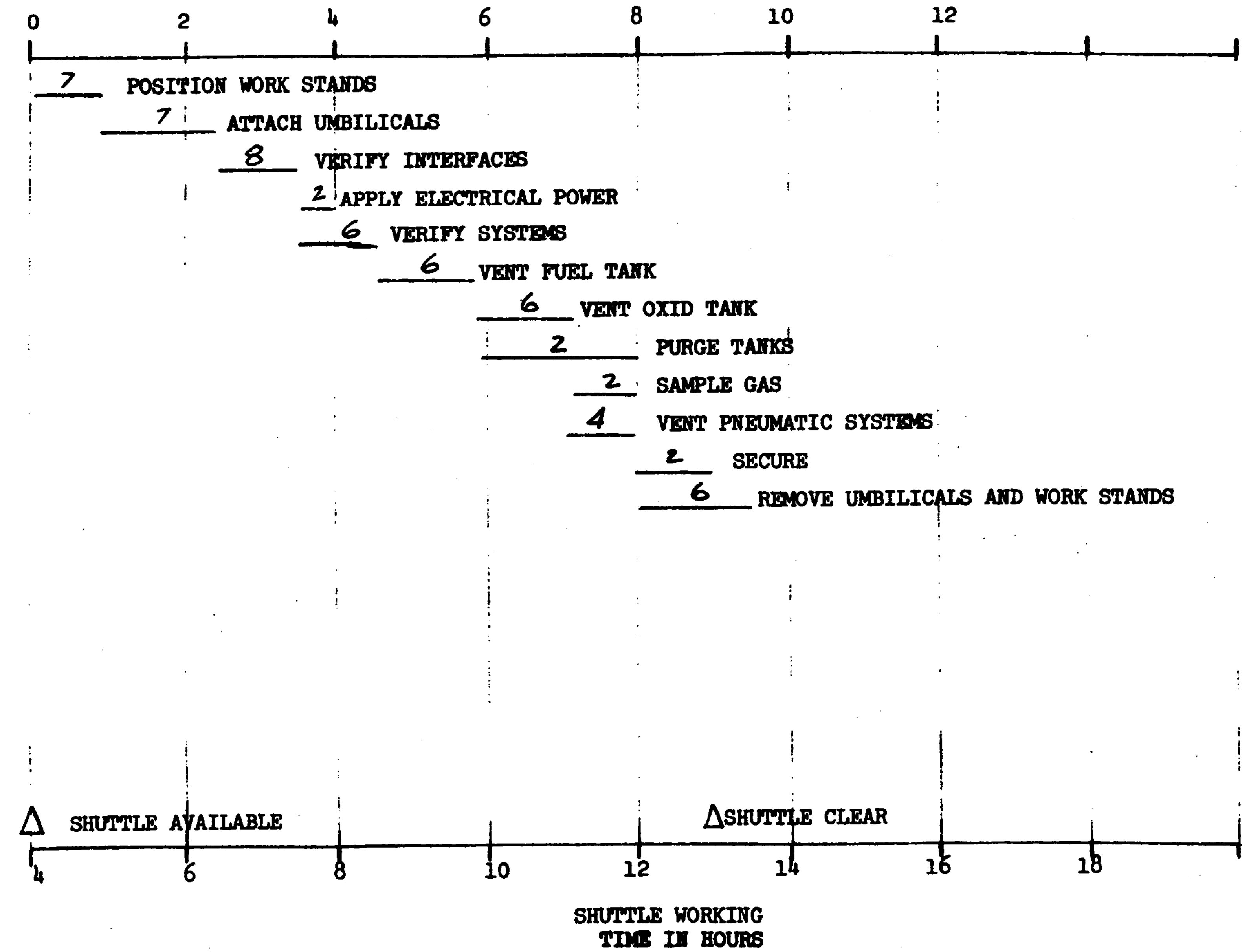
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F WTR	PREPARE PRELIMINARY M&R SCHEDULE	1.1.1



OPTION NUMBER 3F WTR	FUNCTION TITLE ANALYZE T/M FOR UNSCHEDULE M&R	FLOW BLOCK NO. 1.1.2



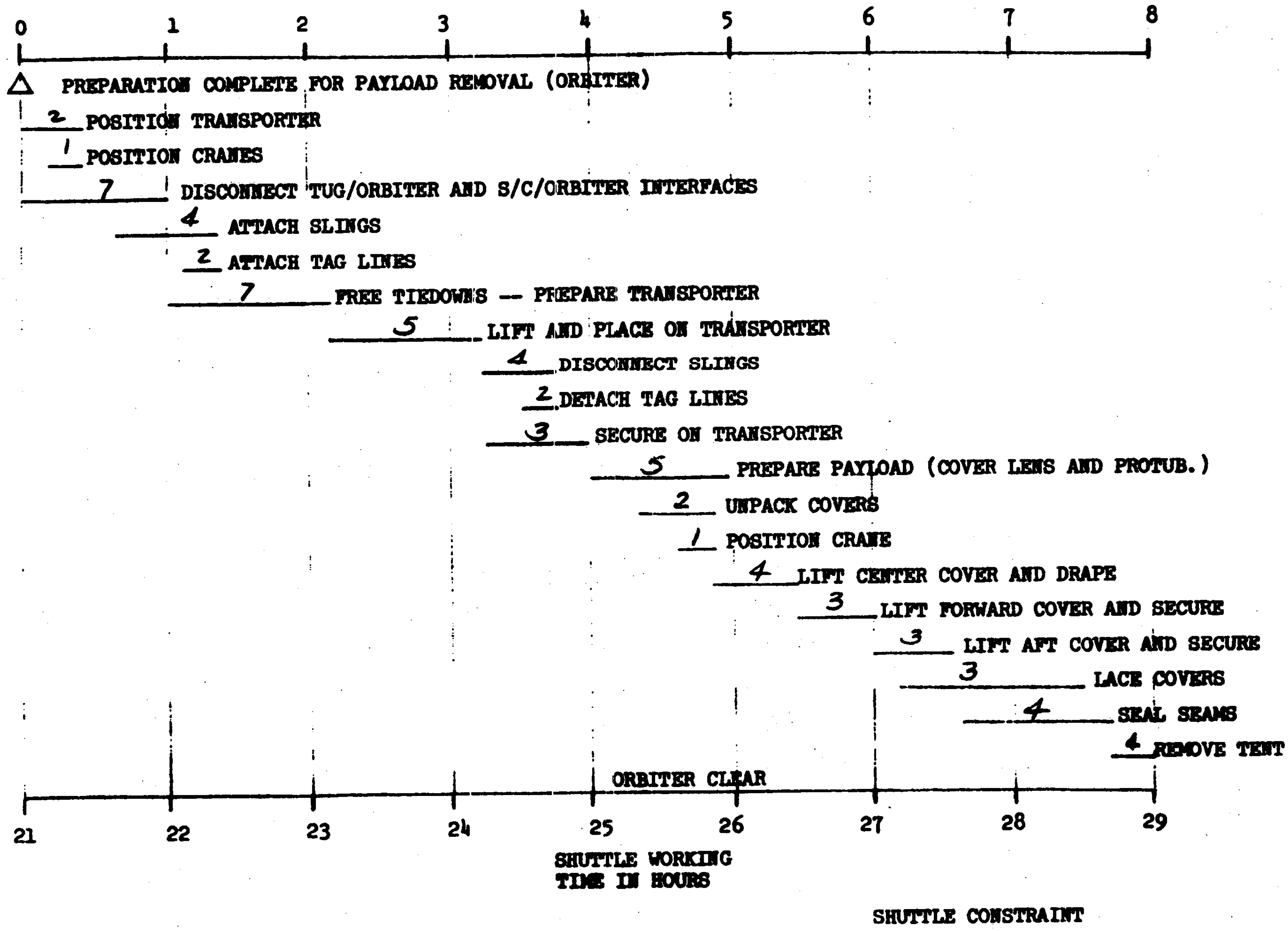
OPTION NUMBER 3F WTR	FUNCTION TITLE TUG GROUND SAFING AT SAFING AREA	FLOW BLOCK NO. 3.1.1



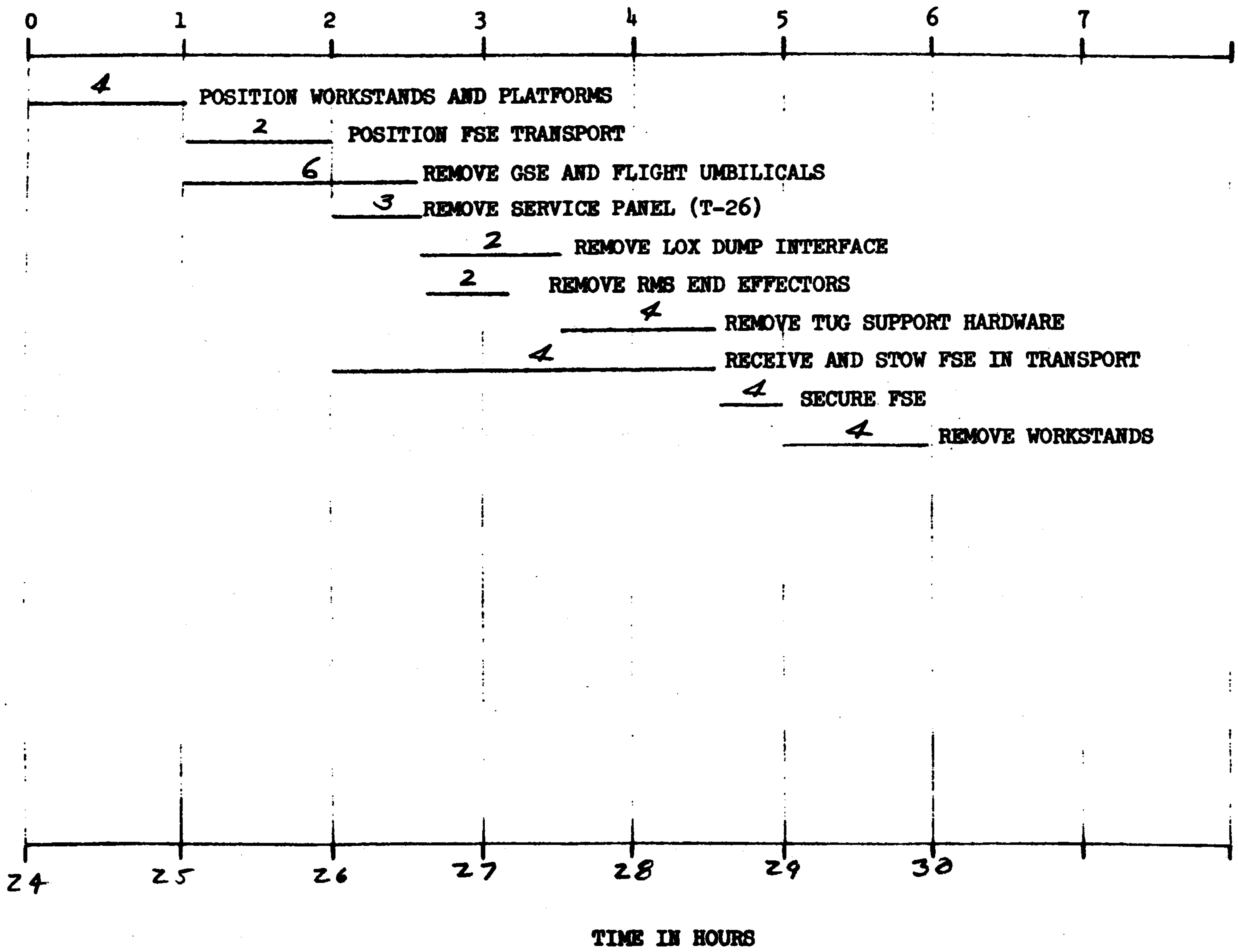
NOTE: NO RESIDUAL LIQUIDS

SHUTTLE CONSTRAINTS

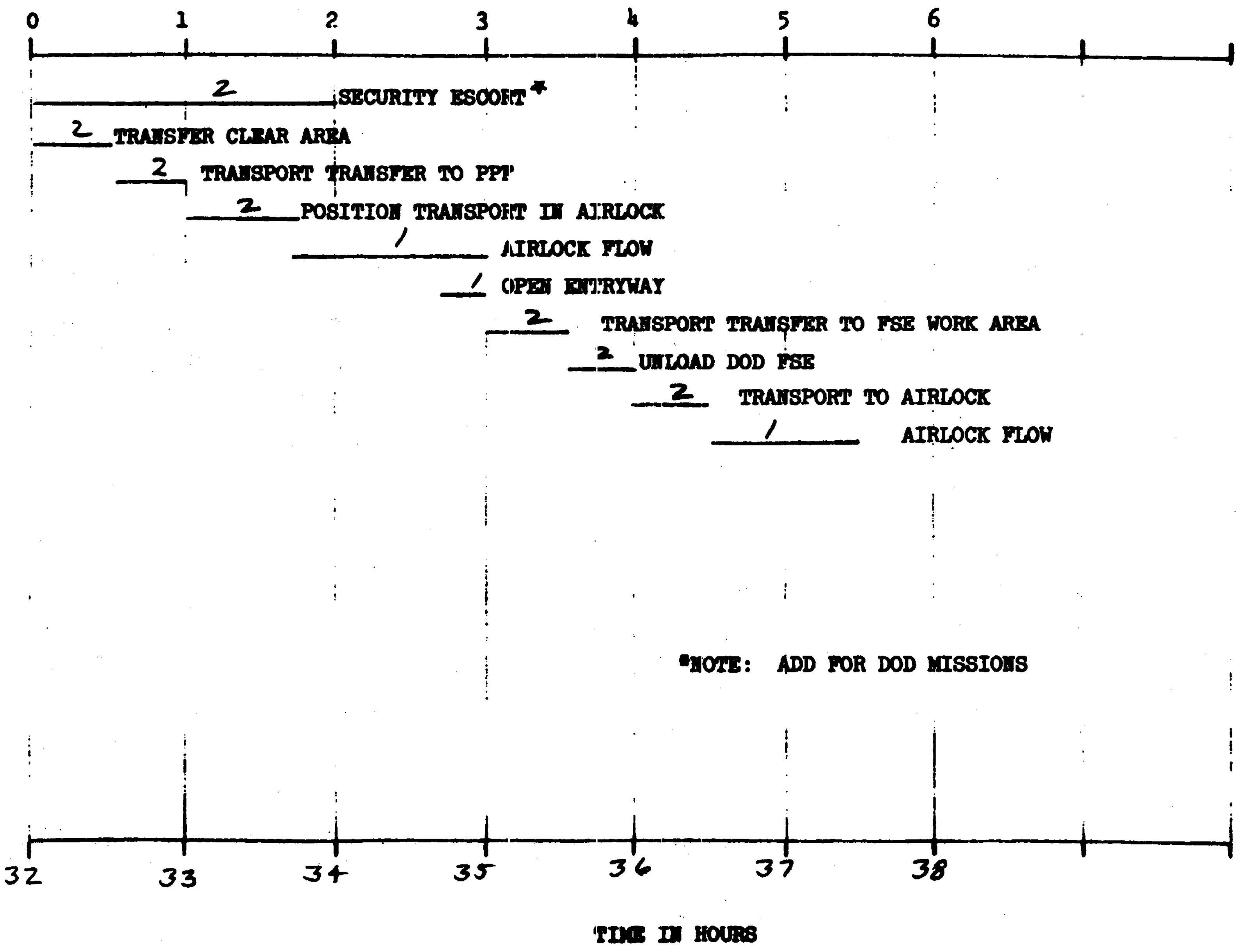
OPTION NUMBER 3F WTR	FUNCTION TITLE RECOVER TUG AND S/C AT MCF	FLOW BLOCK NO. 3.2.5



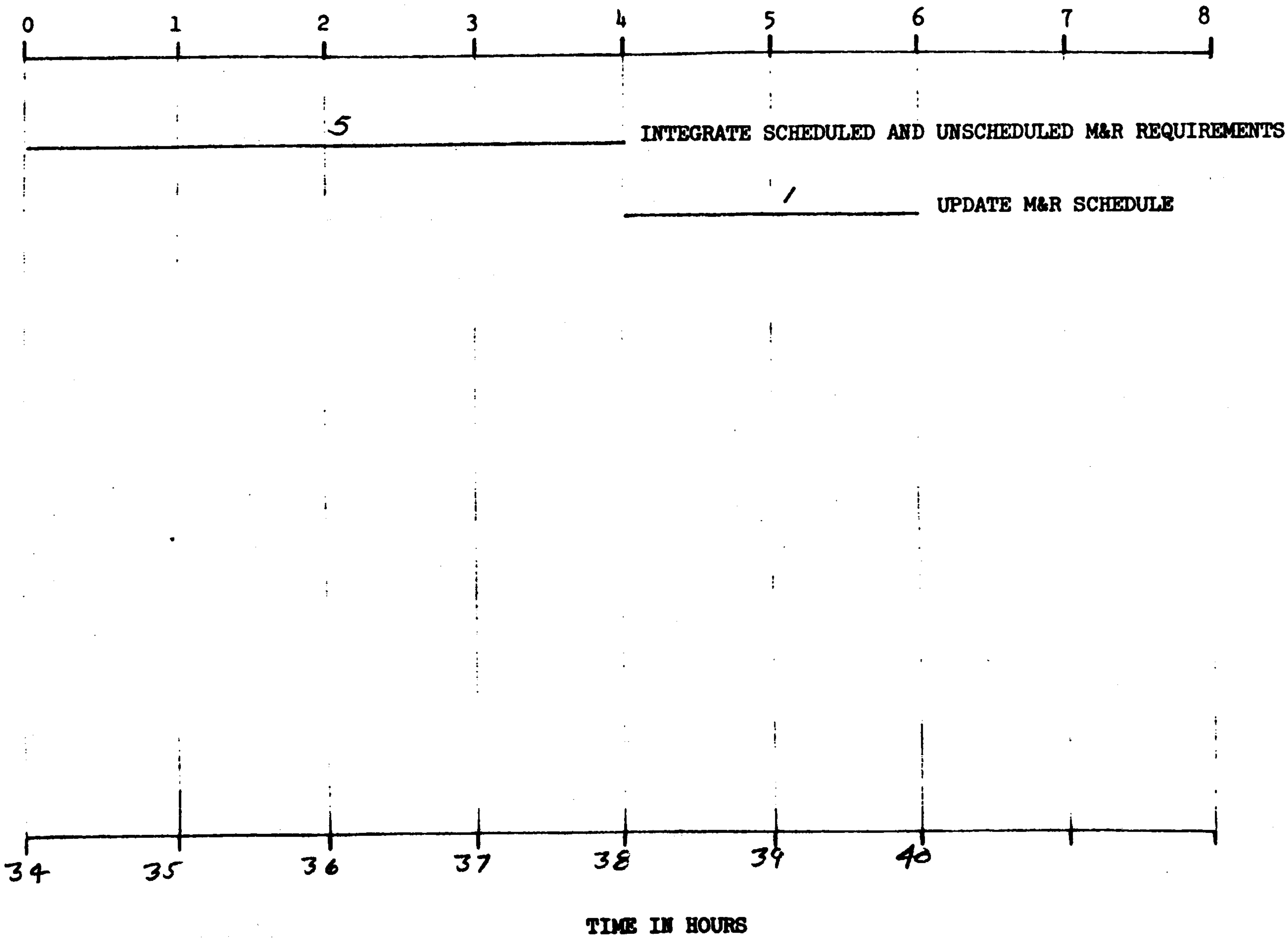
OPTION NUMBER 3F WTR ALL	FUNCTION TITLE RECOVER FSE (PAYLOAD BAY) EQUIPMENT	FLOW BLOCK NO. 3.2.7



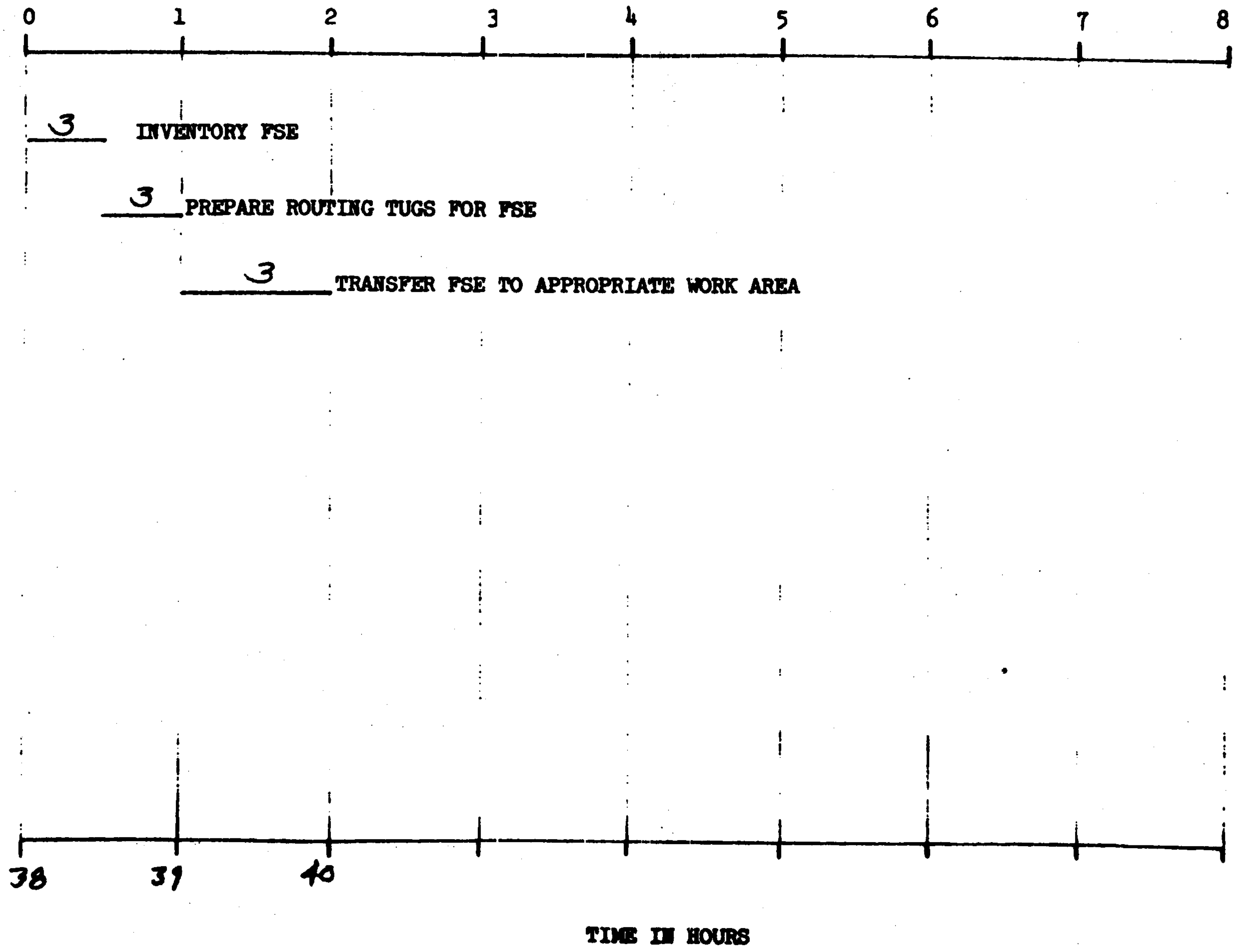
OPTION NUMBER	3F WTR	FUNCTION TITLE	TRANSFER FSE TO PPF	FLOW BLOCK NO.	3.2.8



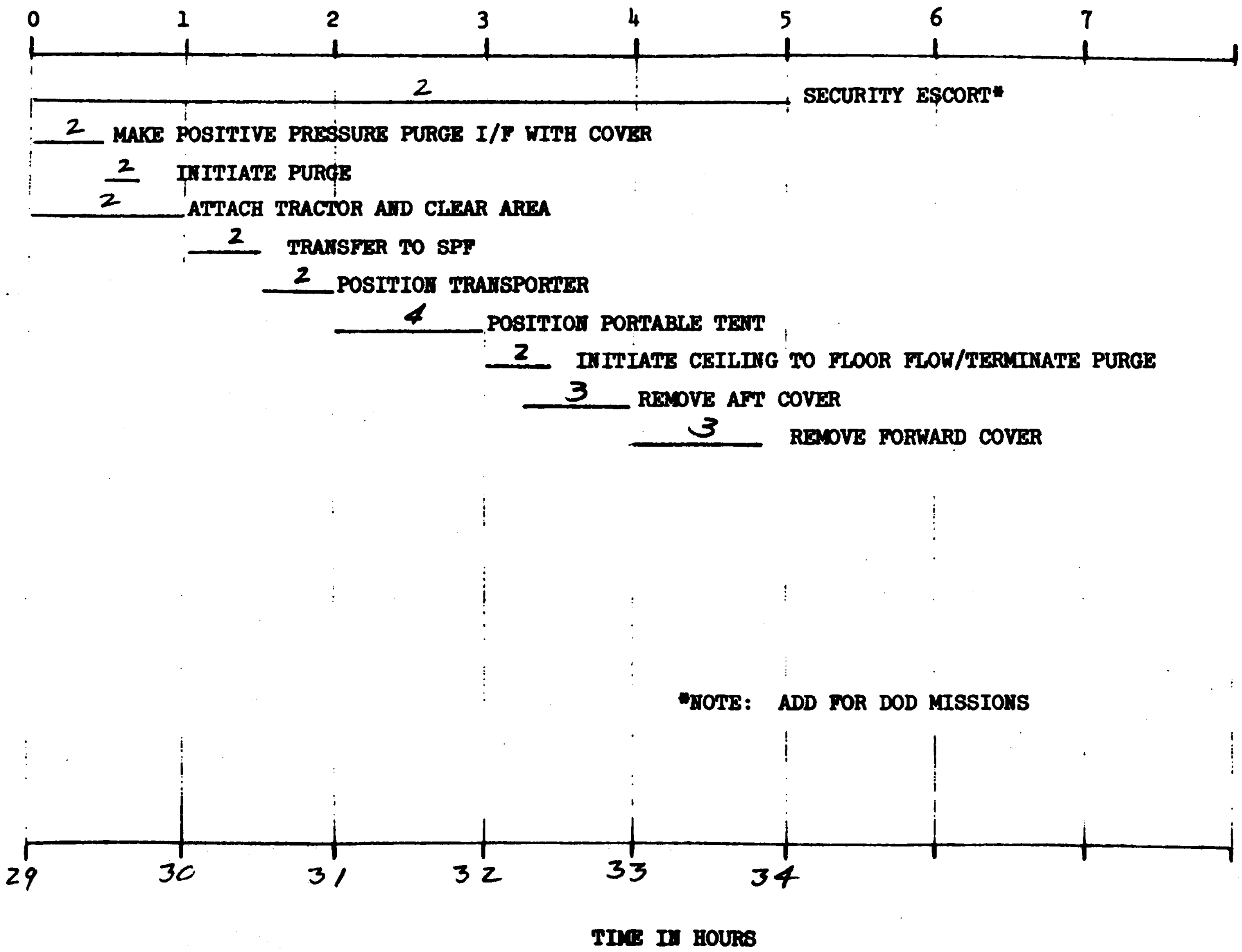
OPTION NUMBER 3F WTR	FUNCTION TITLE UPDATE M&R SCHEDULE	FLOW BLOCK NO. 1.1.3



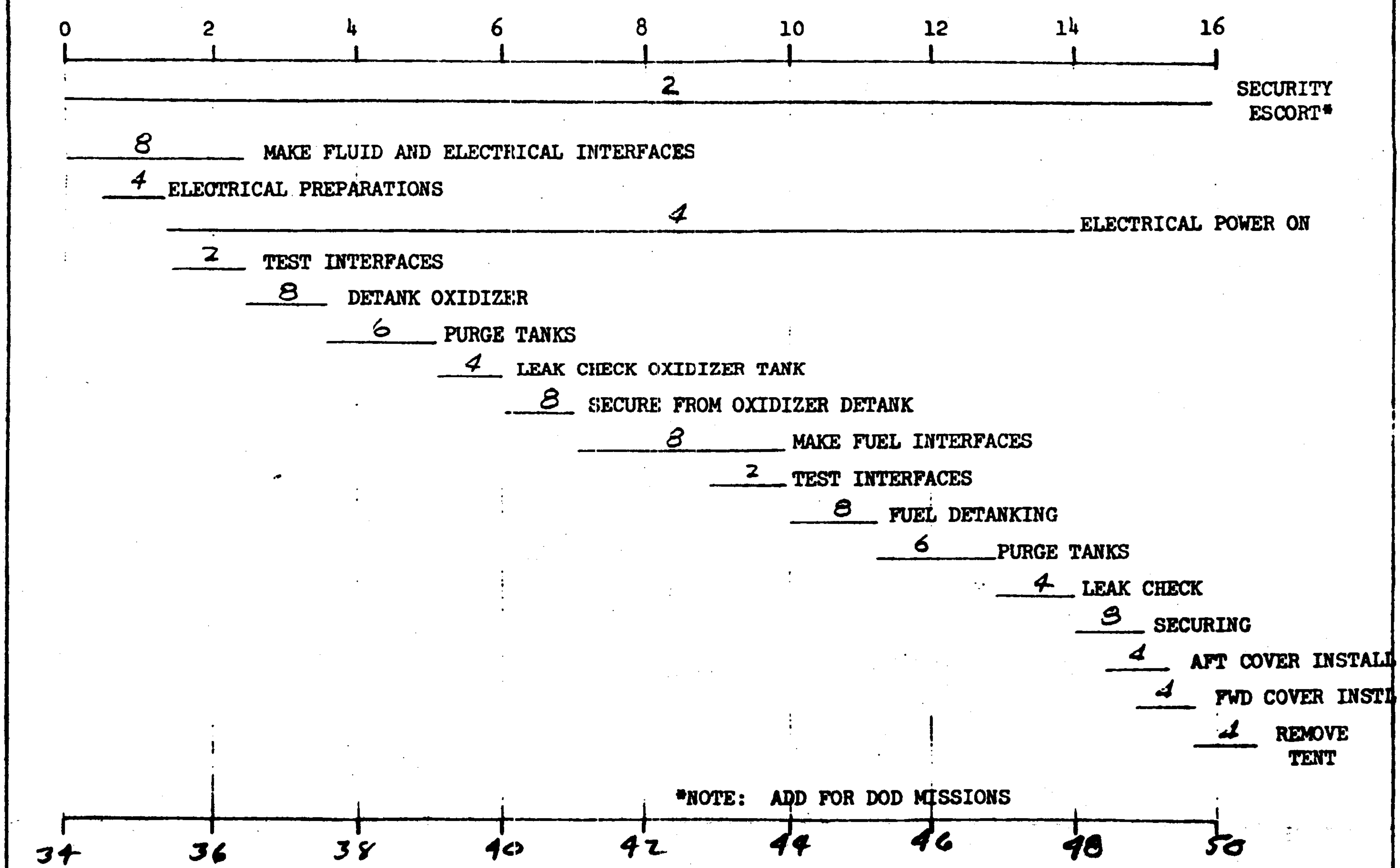
OPTION NUMBER 3F WTR	FUNCTION TITLE RECEIVE FSE AT TPF/PPF	FLOW BLOCK NO. 1.1.15



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F WTR	TRANSFER TUG AND S/C TO SPF	3.1.4



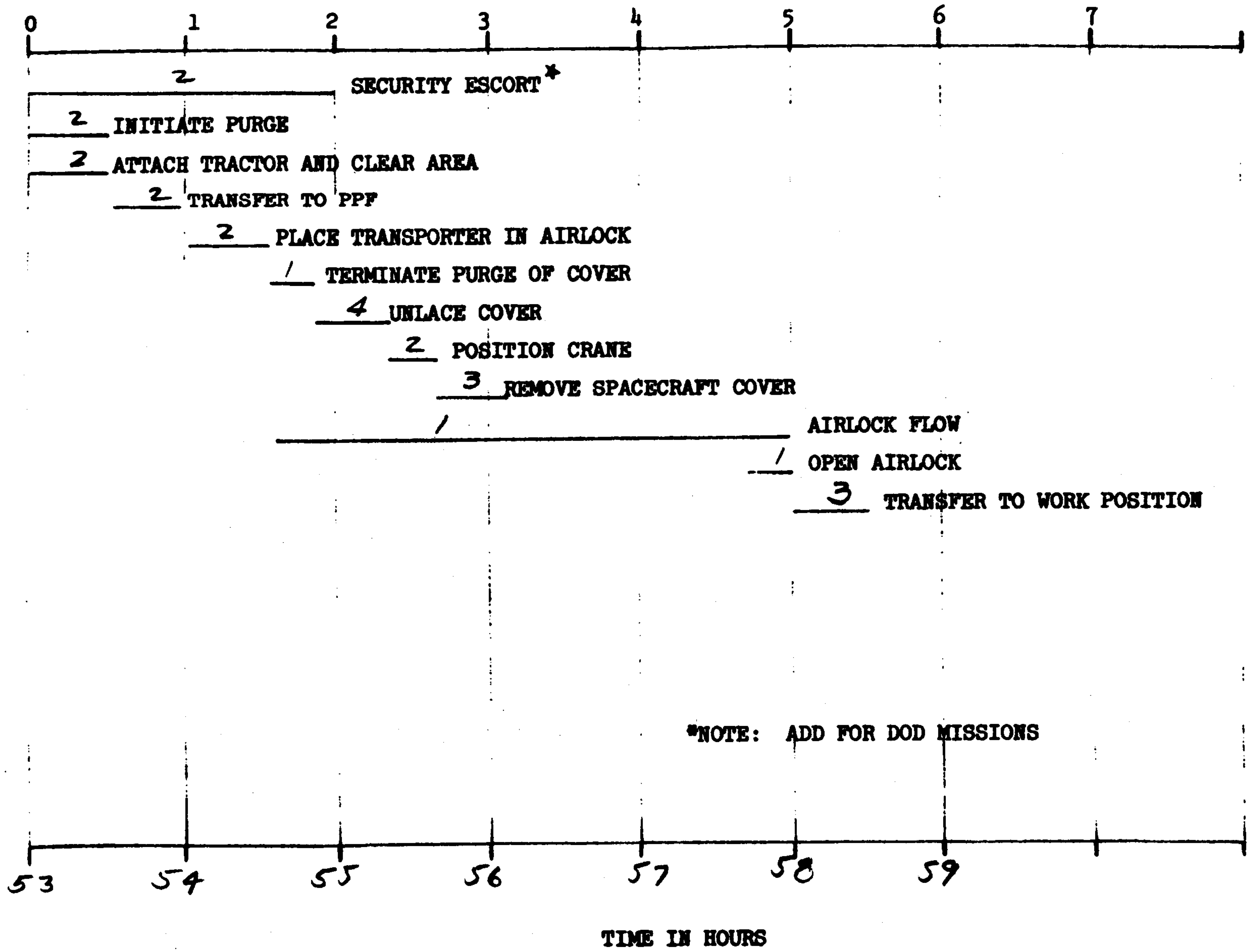
OPTION NUMBER 3F WTR	FUNCTION TITLE TUG SAFING	FLOW BLOCK NO. 3.1.7



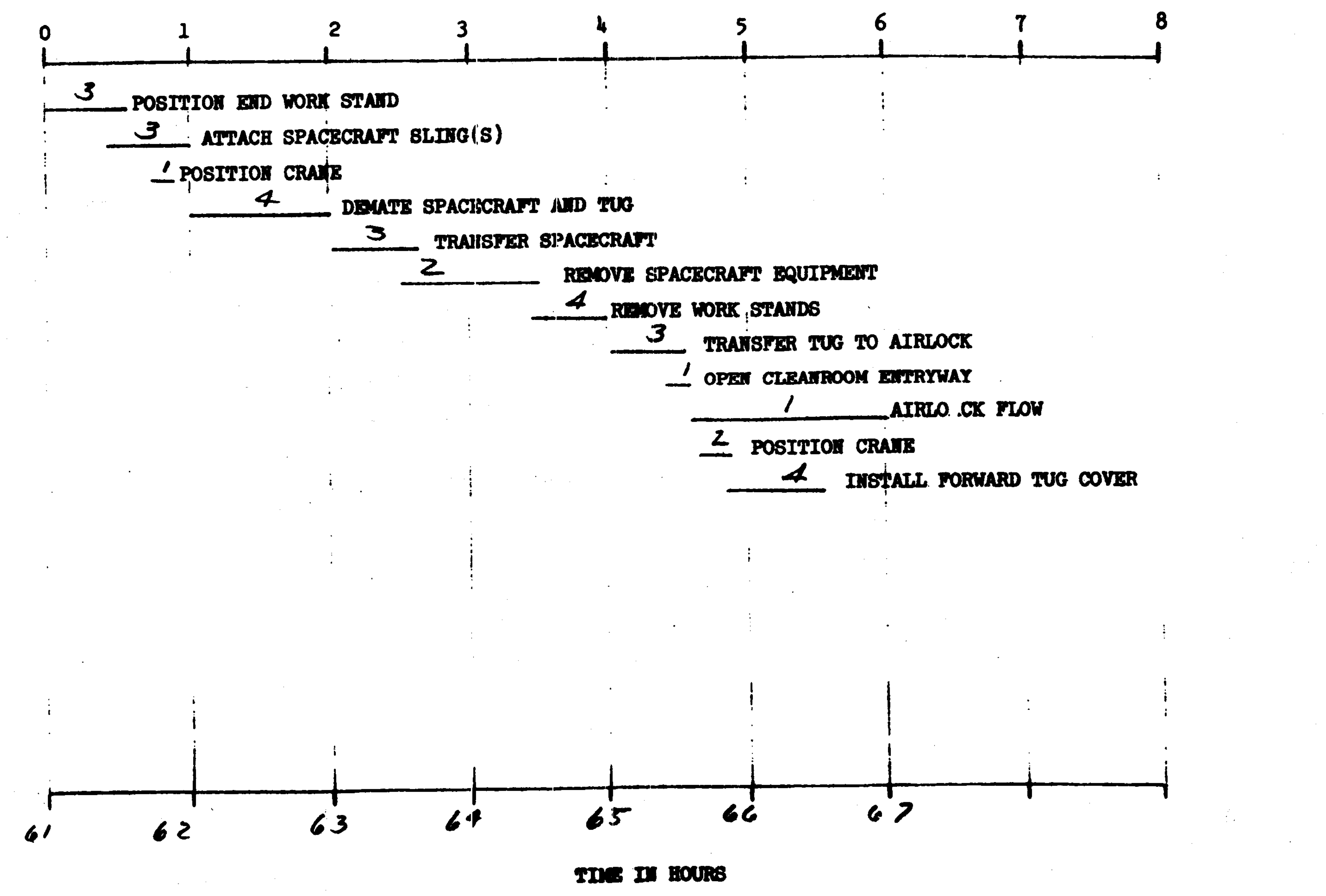
NOTES: BIPROPELLANT AT SPF

TIME IN HOURS

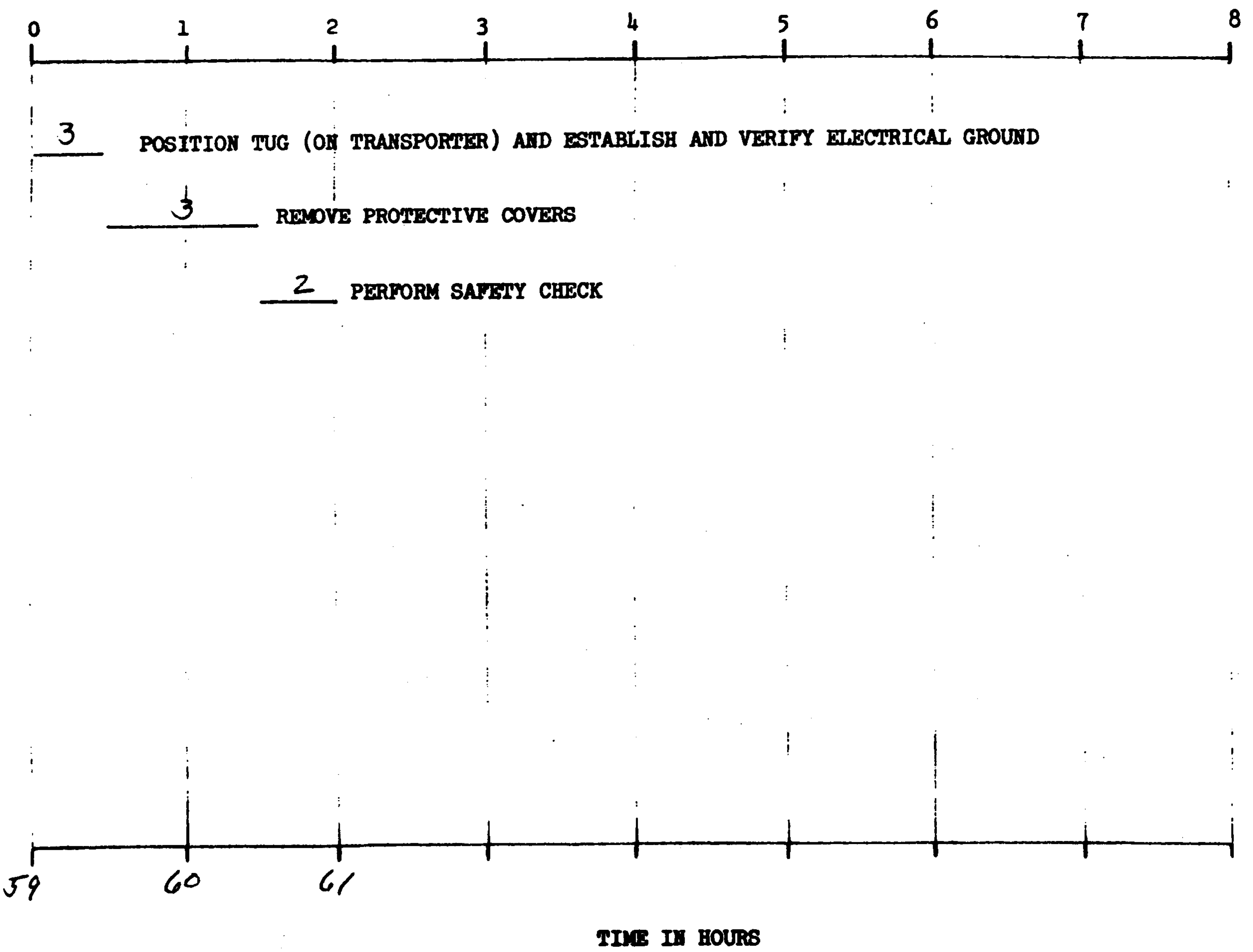
OPTION NUMBER 3F WTR	FUNCTION TITLE TRANSFER TUG AND S/C TO PPF	FLOW BLOCK NO. 3.3.1



OPTION NUMBER 3F WTR	FUNCTION TITLE DEMATE TUG AND SPACECRAFT	FLOW BLOCK NO. 3.3.7



OPTION NUMBER 3F WTR	FUNCTION TITLE RECEIVE TUG AT TPF/PPF	FLOW BLOCK NO. 1.1.4



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F WTR	PREPARE FOR INSPECTION AND C/O	1.1.5

0 1 2 3 4 5 6 7 8

6 POSITION WORKSTANDS

6 OPEN ACCESS PANELS/DOORS

3 INSTALL AIR CONDITIONING (BREATHABLE AIR) IN CONFINED AREAS

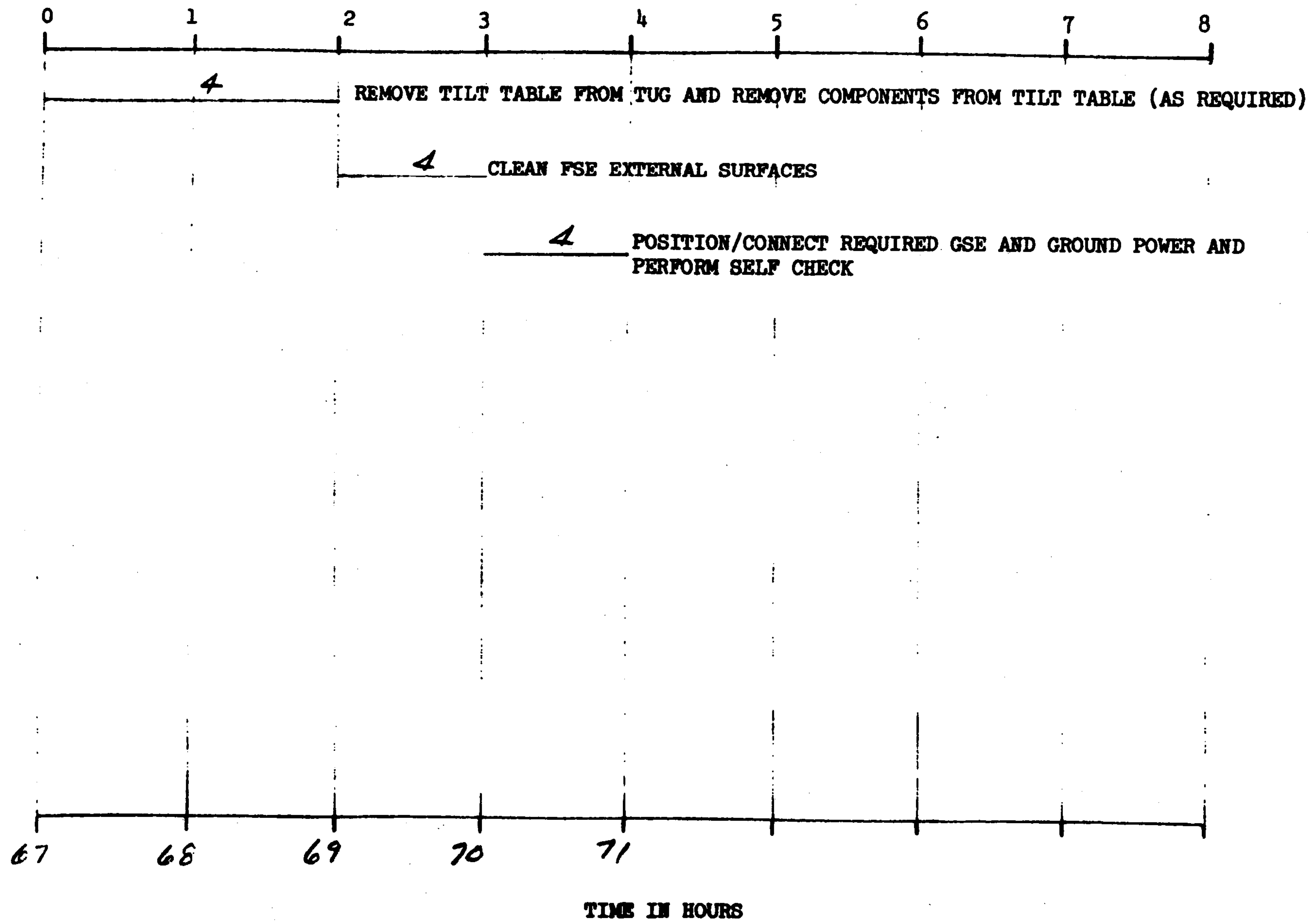
4 REMOVE FORWARD SKIRT METEOROID BARRIER

4 POSITION/CONNECT REQUIRED GSE AND GROUND POWER AND PERFORM SELF CHECK

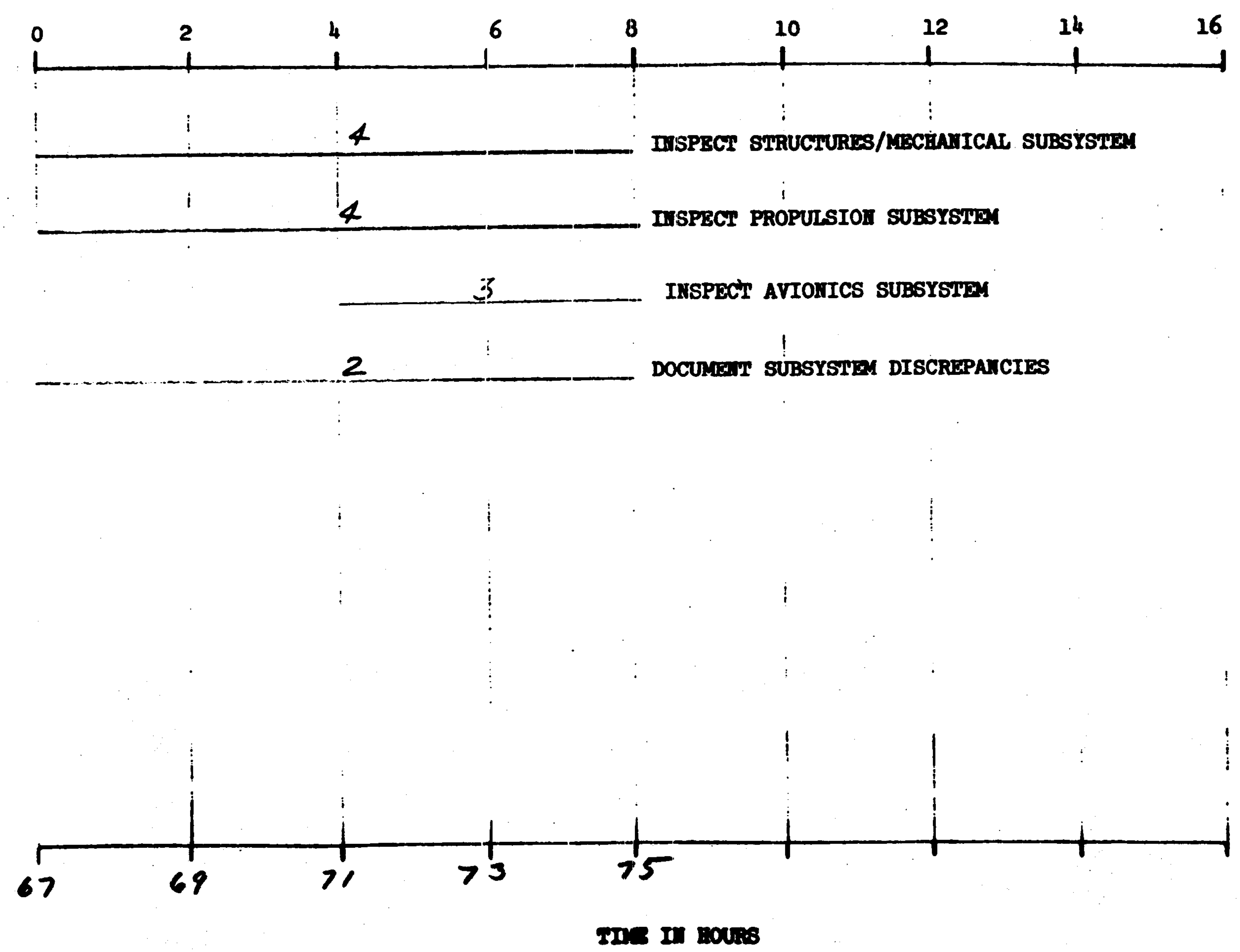
67 68 69 70 71

TIME IN HOURS

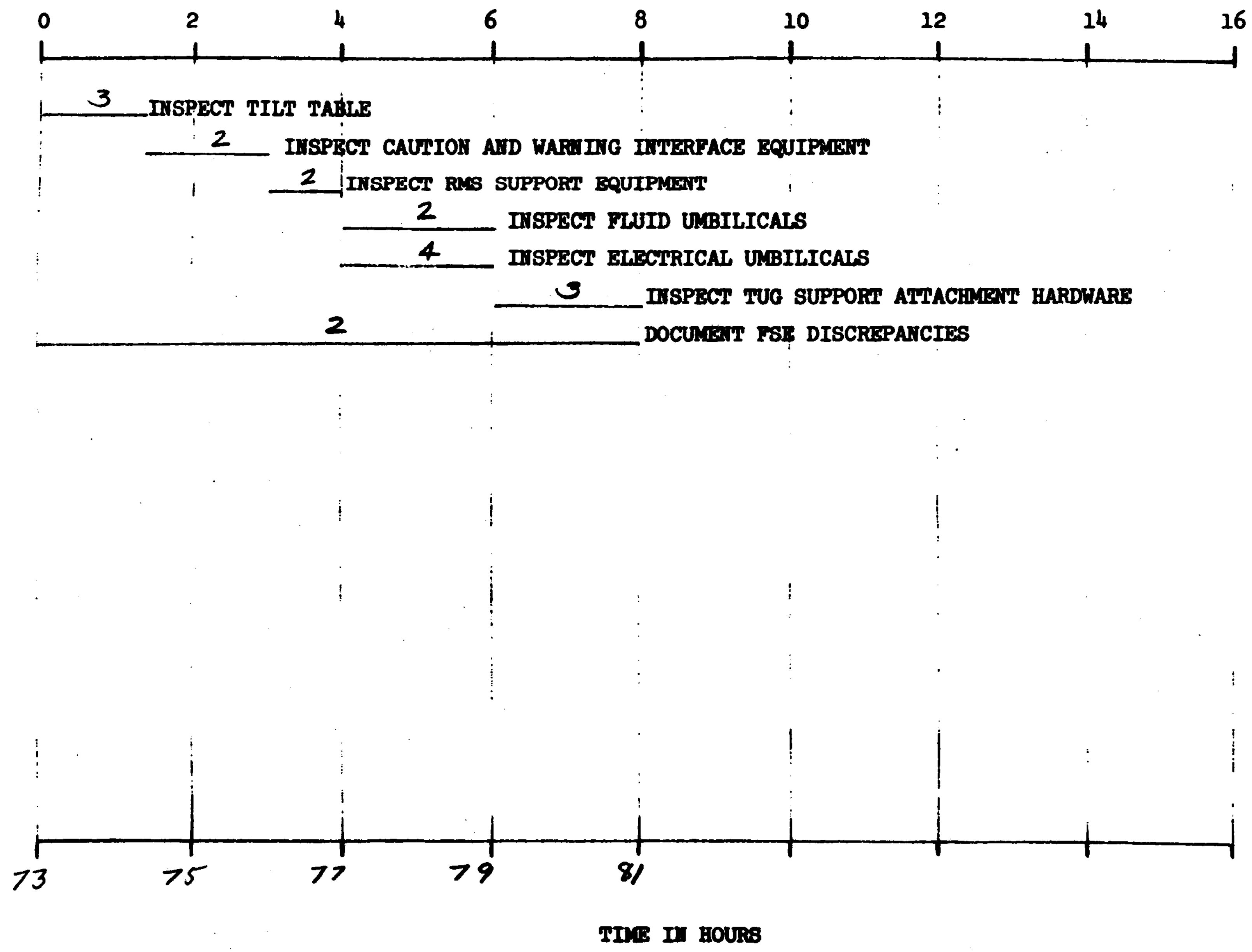
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F WTR	PREPARE FOR INSPECTION	1.1.16



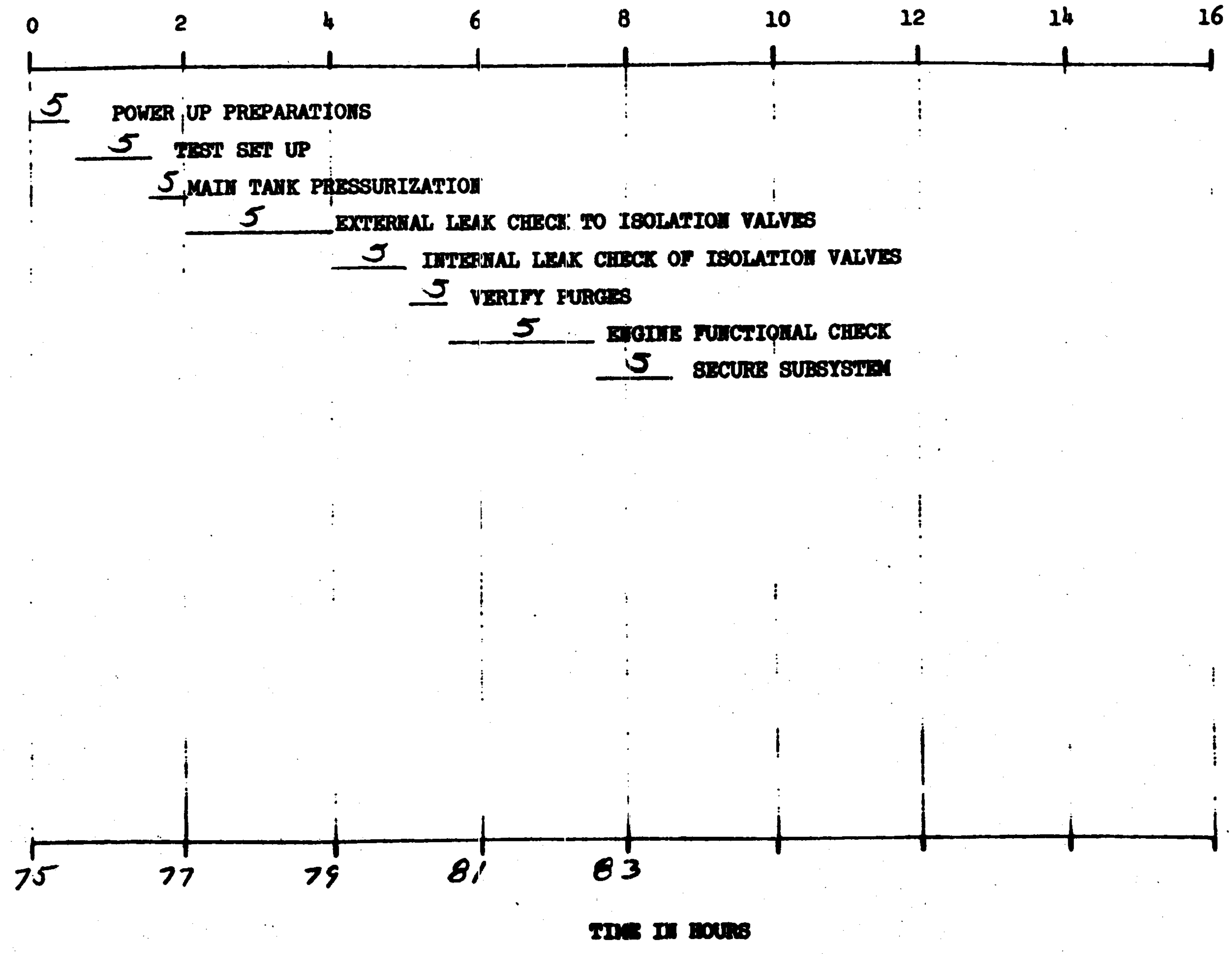
OPTION NUMBER 3F WTR	FUNCTION TITLE PERFORM POST FLIGHT RECEIVING INSPECTION	FLOW BLOCK NO. 1.1.6



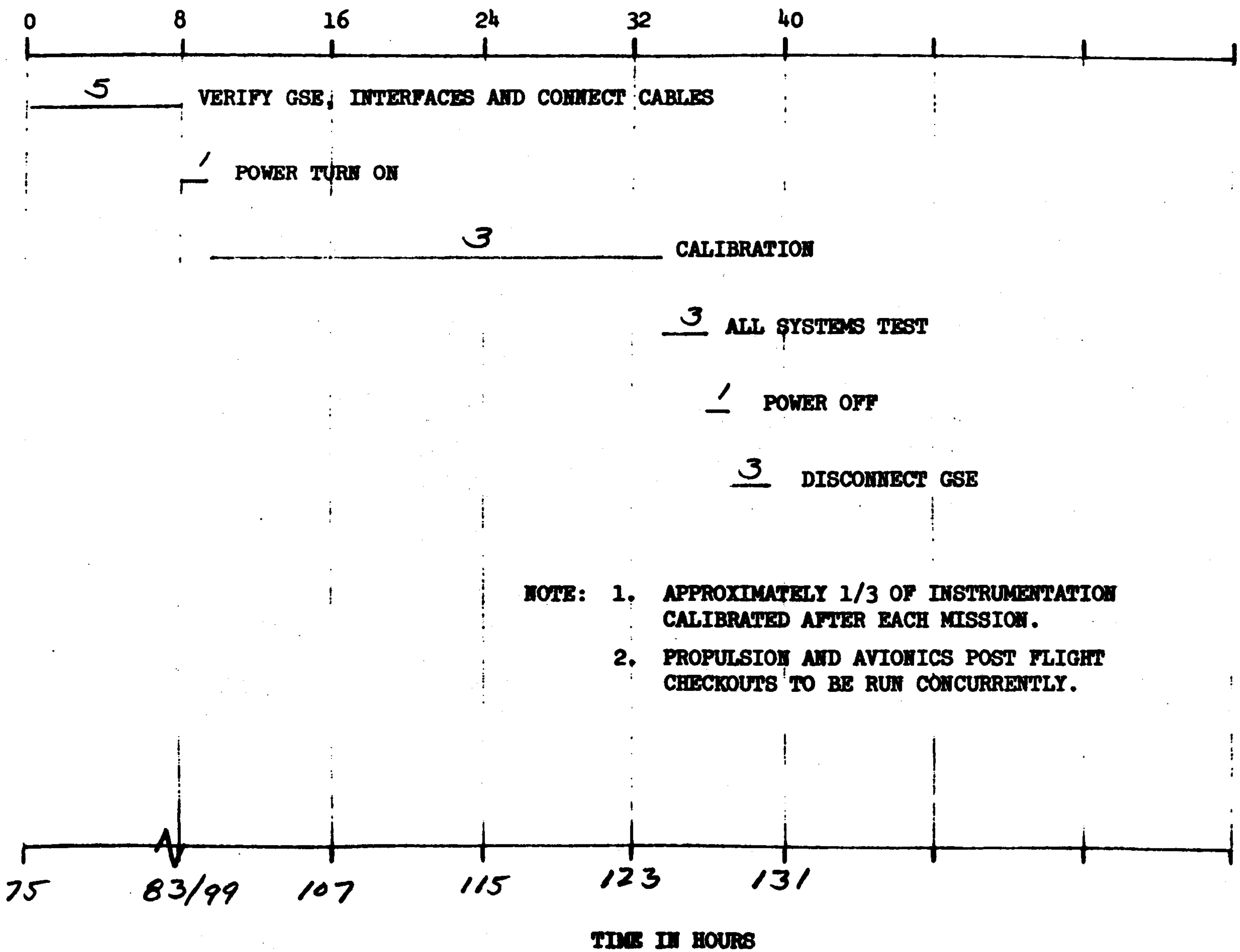
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F WTR	PERFORM FSE POST FLIGHT/RECEIVING INSPECTION	1.1.17



OPTION NUMBER 3F WTR	FUNCTION TITLE POST FLIGHT CHECKOUT - MAIN PROPULSION PRESSURIZATION - COLD HELIUM & GH_2 BLEED	FLOW BLOCK NO. 1.1.7.2



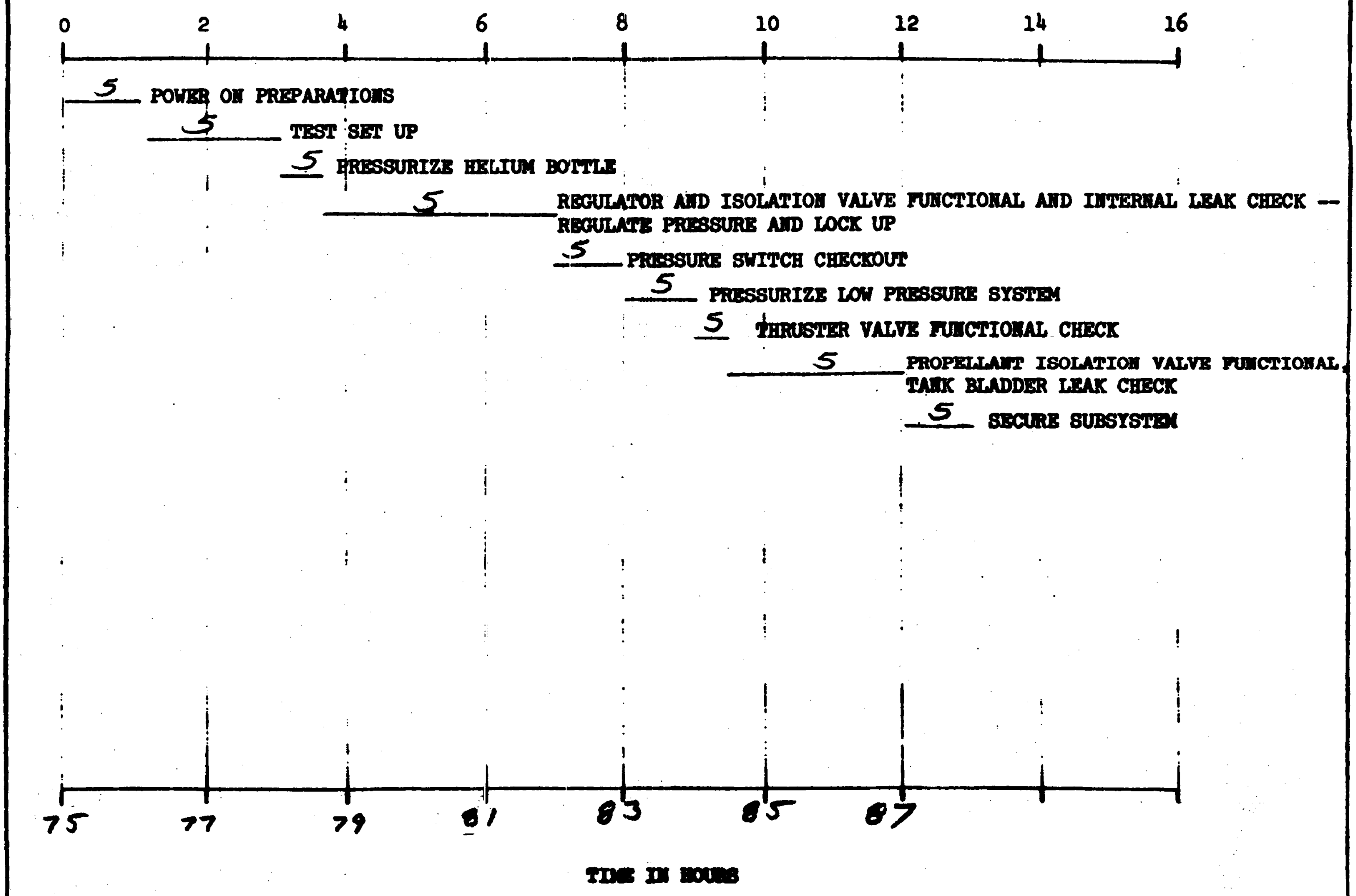
OPTION NUMBER 3F WTR	FUNCTION TITLE POST FLIGHT CHECKOUT - AVIONICS	FLOW BLOCK NO. 1.1.7.9



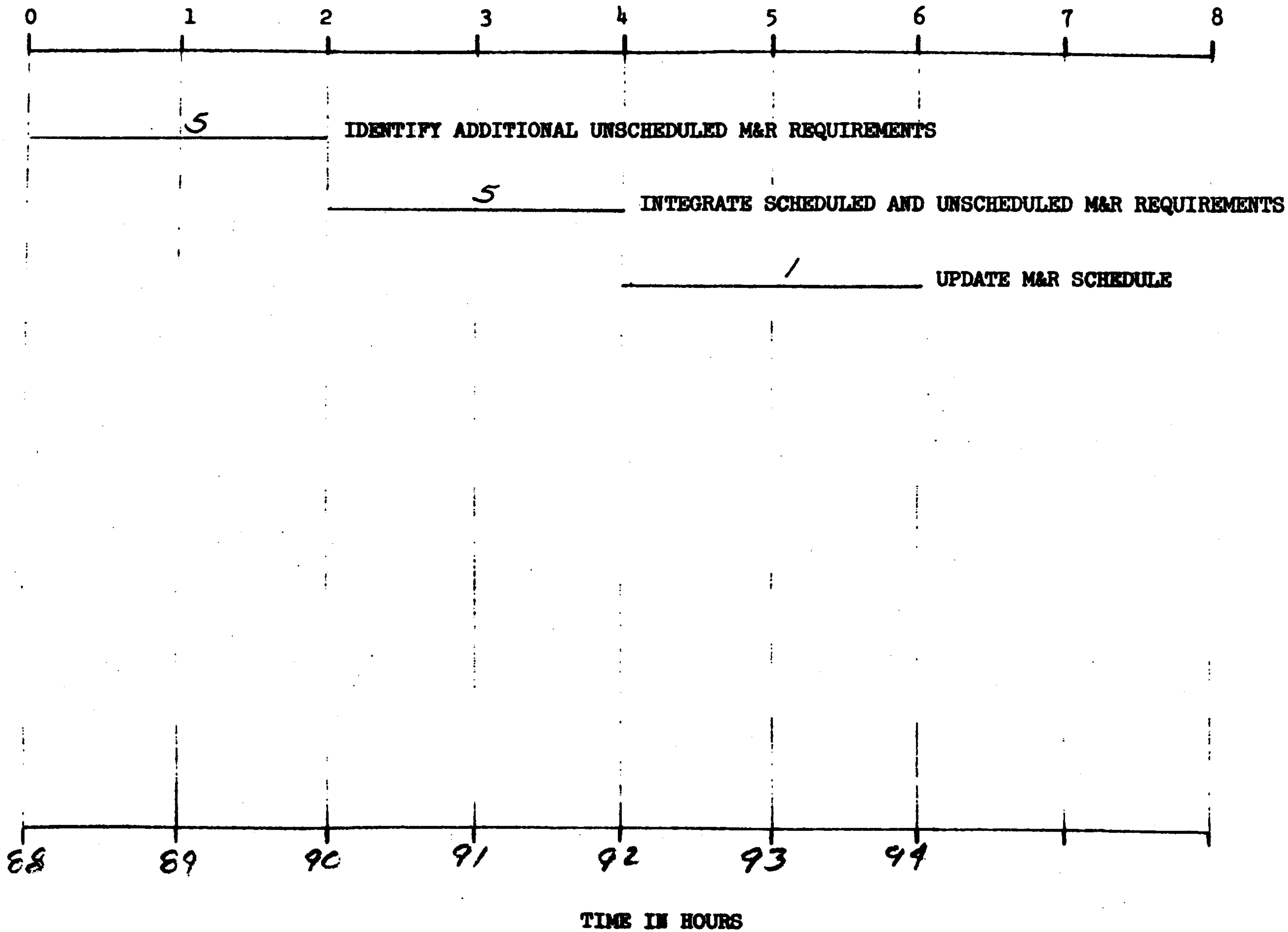
NOTE: 1. APPROXIMATELY 1/3 OF INSTRUMENTATION CALIBRATED AFTER EACH MISSION.

2. PROPULSION AND AVIONICS POST FLIGHT CHECKOUTS TO BE RUN CONCURRENTLY.

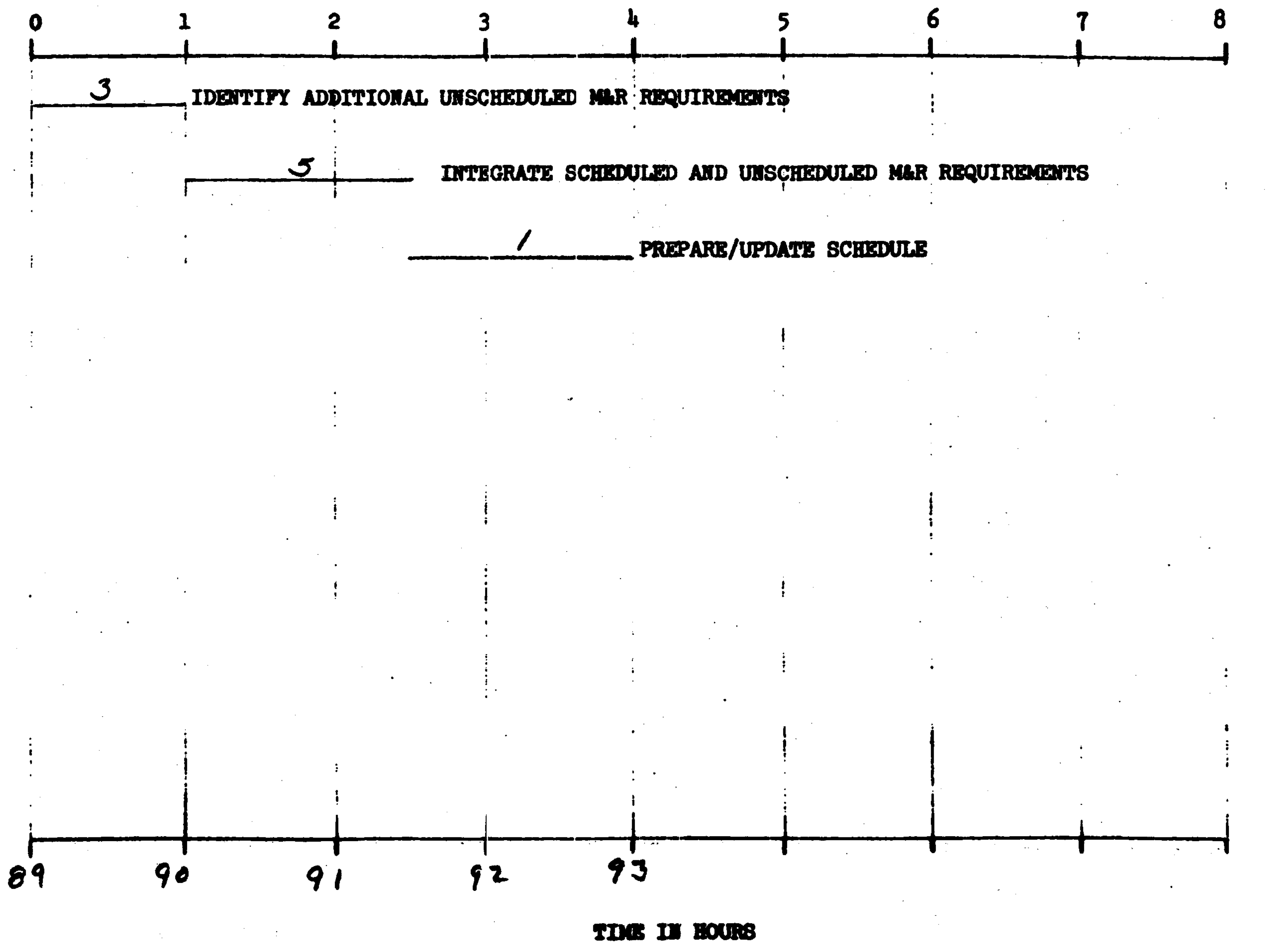
OPTION NUMBER 3F WTR	FUNCTION TITLE POST FLIGHT CHECKOUT - APS SUBSYSTEM - BIPROPELLANT	FLOW BLOCK NO. 1.1.7.7



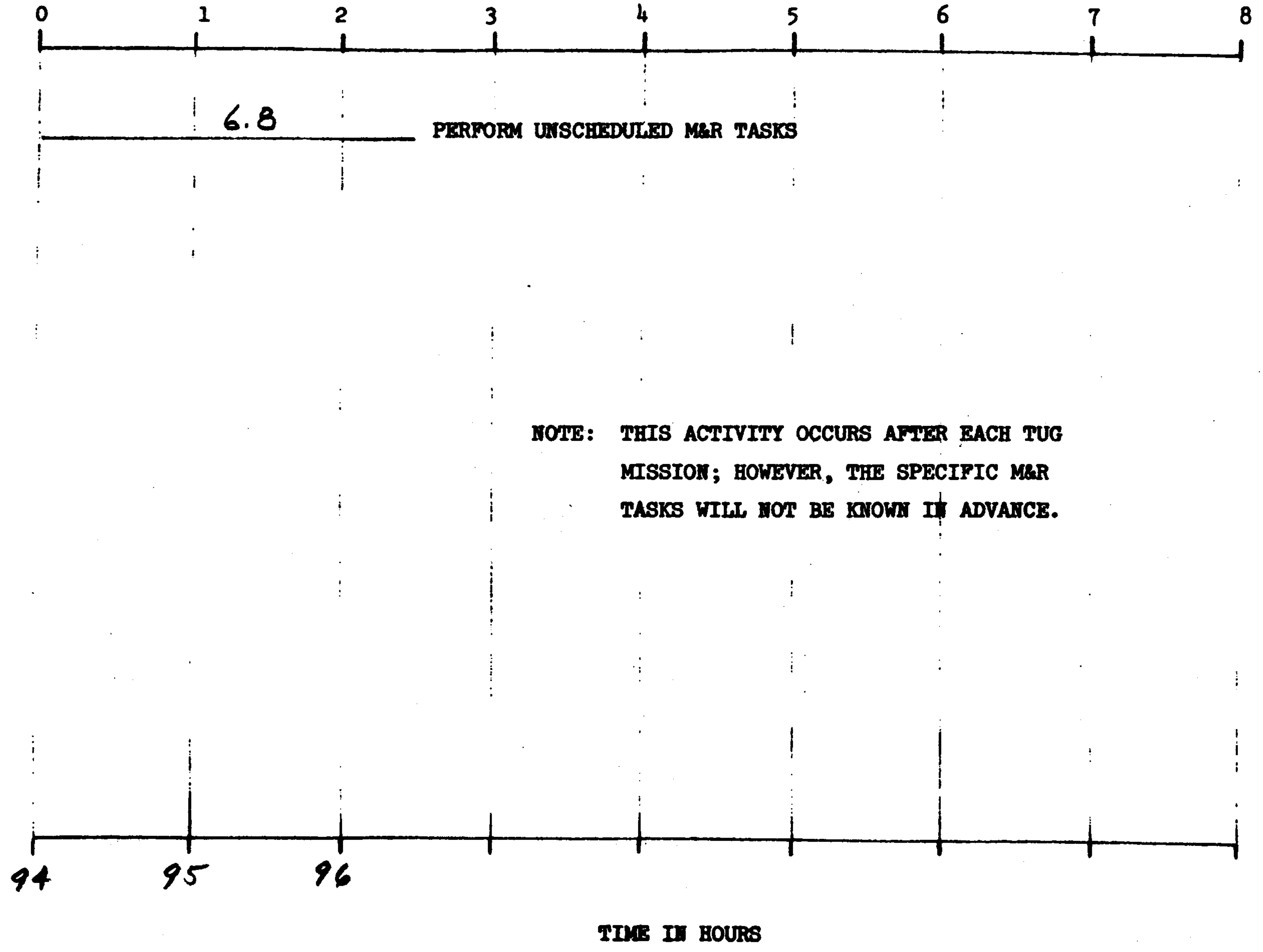
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F WTR	PREPARE/UPDATE M&R SCHEDULE	1.1.10



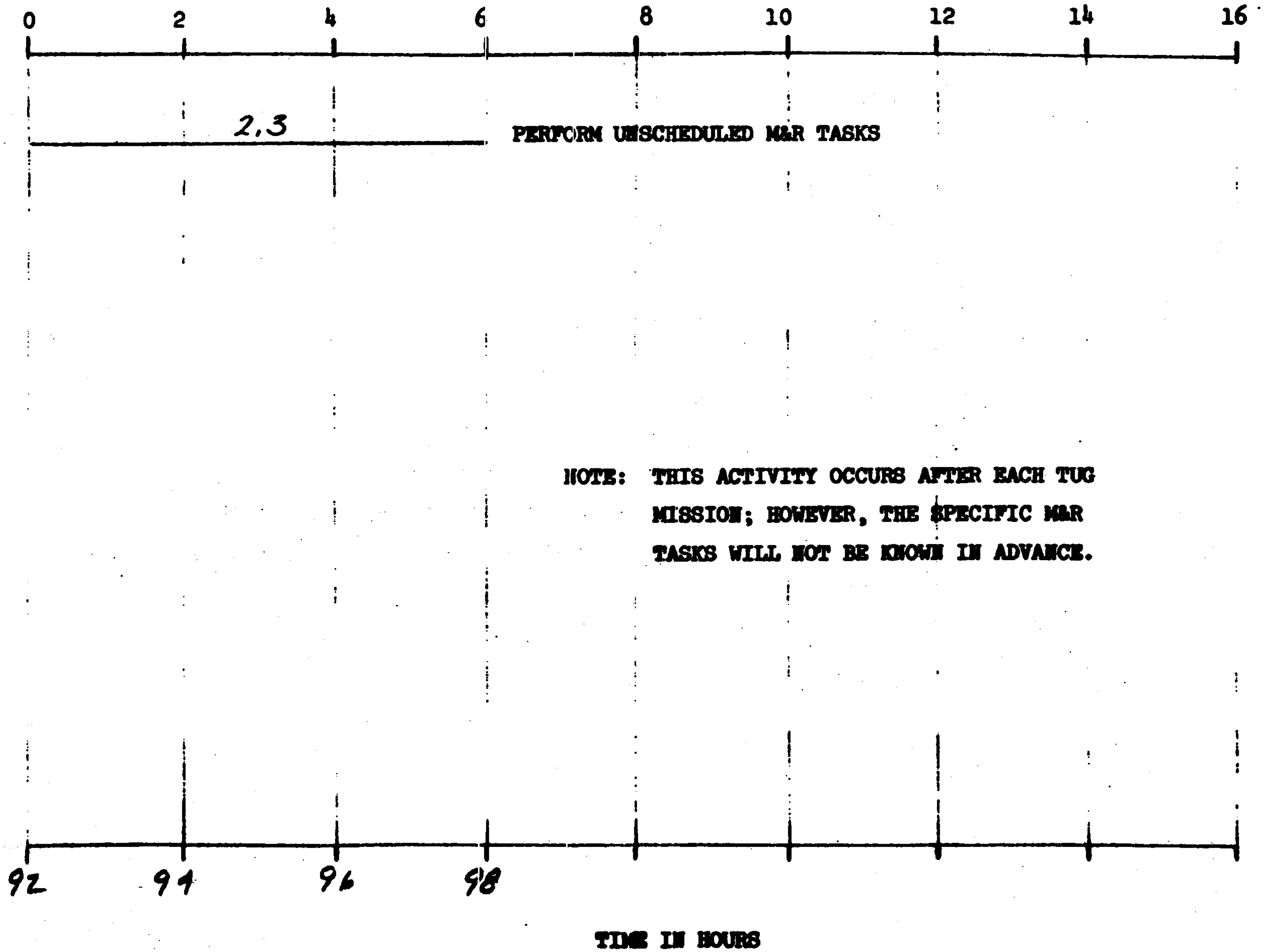
OPTION NUMBER 3F WTR	FUNCTION TITLE PREPARE/UPDATE M&R SCHEDULE	FLOW BLOCK NO. 1.1.18



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F WTR	PERFORM STRUCTURAL/MECHANICAL M&R	1.1.11

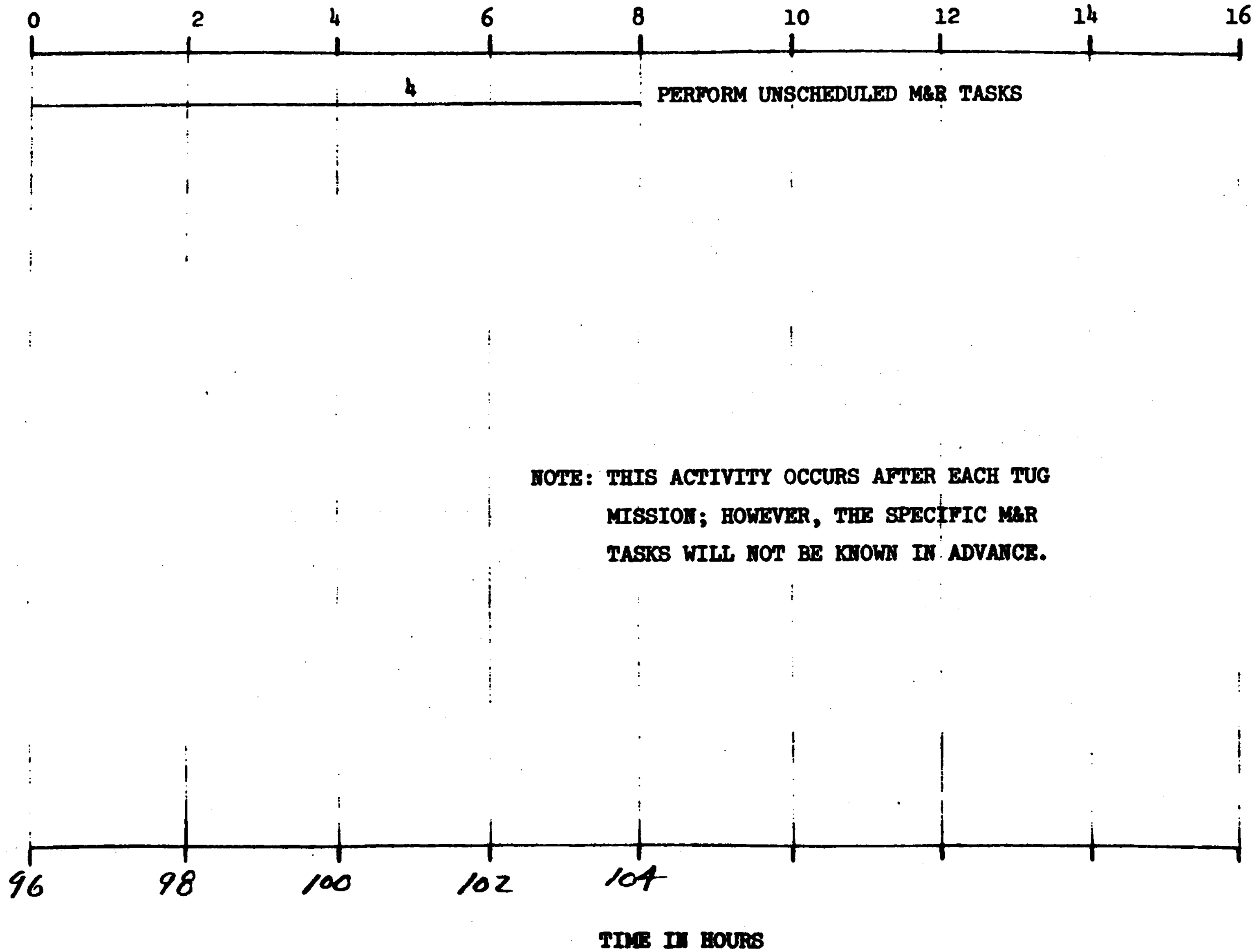


OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F WTR	PERFORM PROPULSION M&R	1.1.12



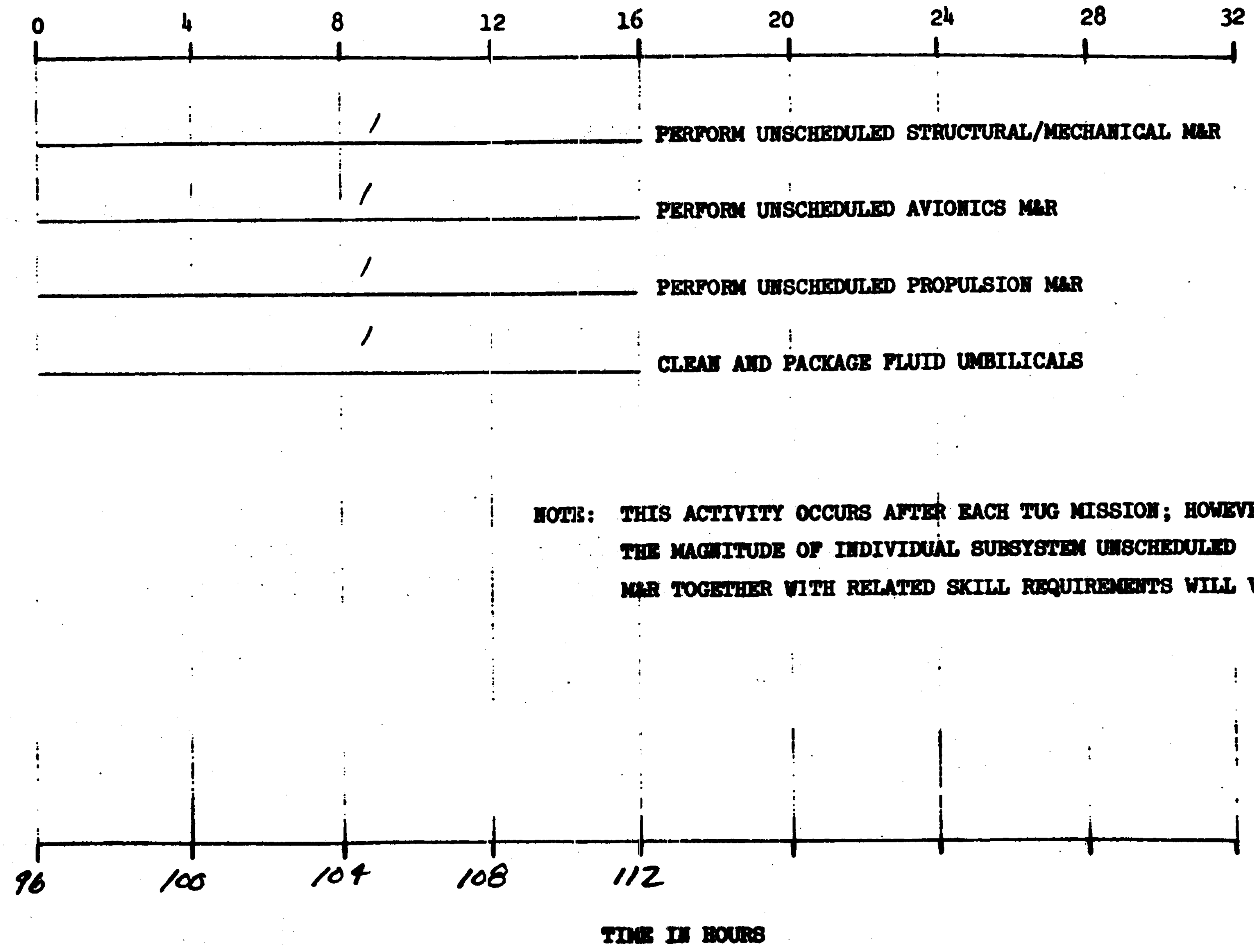
NOTE: THIS ACTIVITY OCCURS AFTER EACH TUG MISSION; HOWEVER, THE SPECIFIC M&R TASKS WILL NOT BE KNOWN IN ADVANCE.

OPTION NUMBER 3F WTR	FUNCTION TITLE PERFORM AVIONICS M&R	FLOW BLOCK NO. 1.1.13



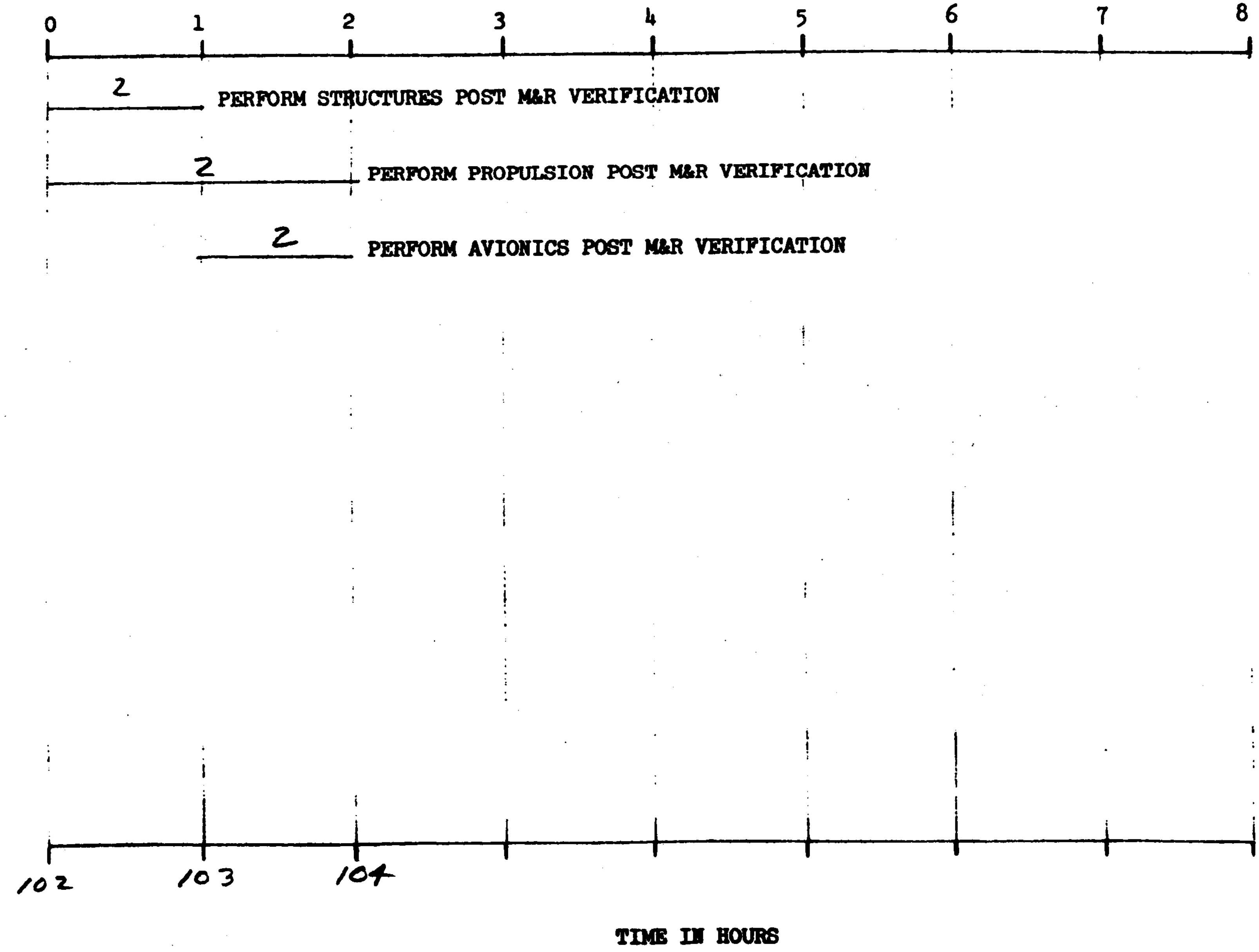
NOTE: THIS ACTIVITY OCCURS AFTER EACH TUG MISSION; HOWEVER, THE SPECIFIC M&R TASKS WILL NOT BE KNOWN IN ADVANCE.

OPTION NUMBER 3F WTR	FUNCTION TITLE PERFORM FSE M&R	FLOW BLOCK NO. 1.1.19

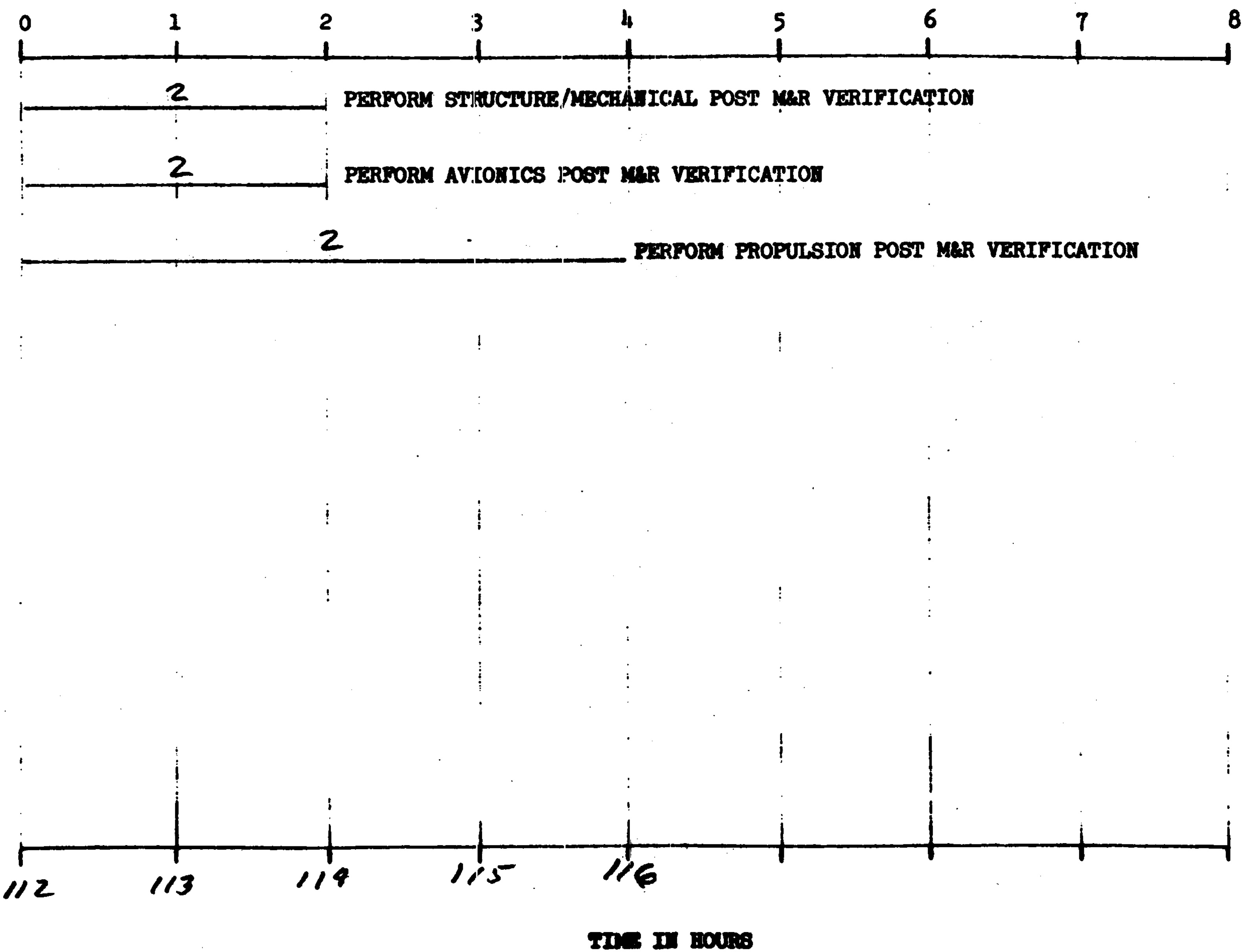


NOTE: THIS ACTIVITY OCCURS AFTER EACH TUG MISSION; HOWEVER, THE MAGNITUDE OF INDIVIDUAL SUBSYSTEM UNSCHEDULED M&R TOGETHER WITH RELATED SKILL REQUIREMENTS WILL VARY.

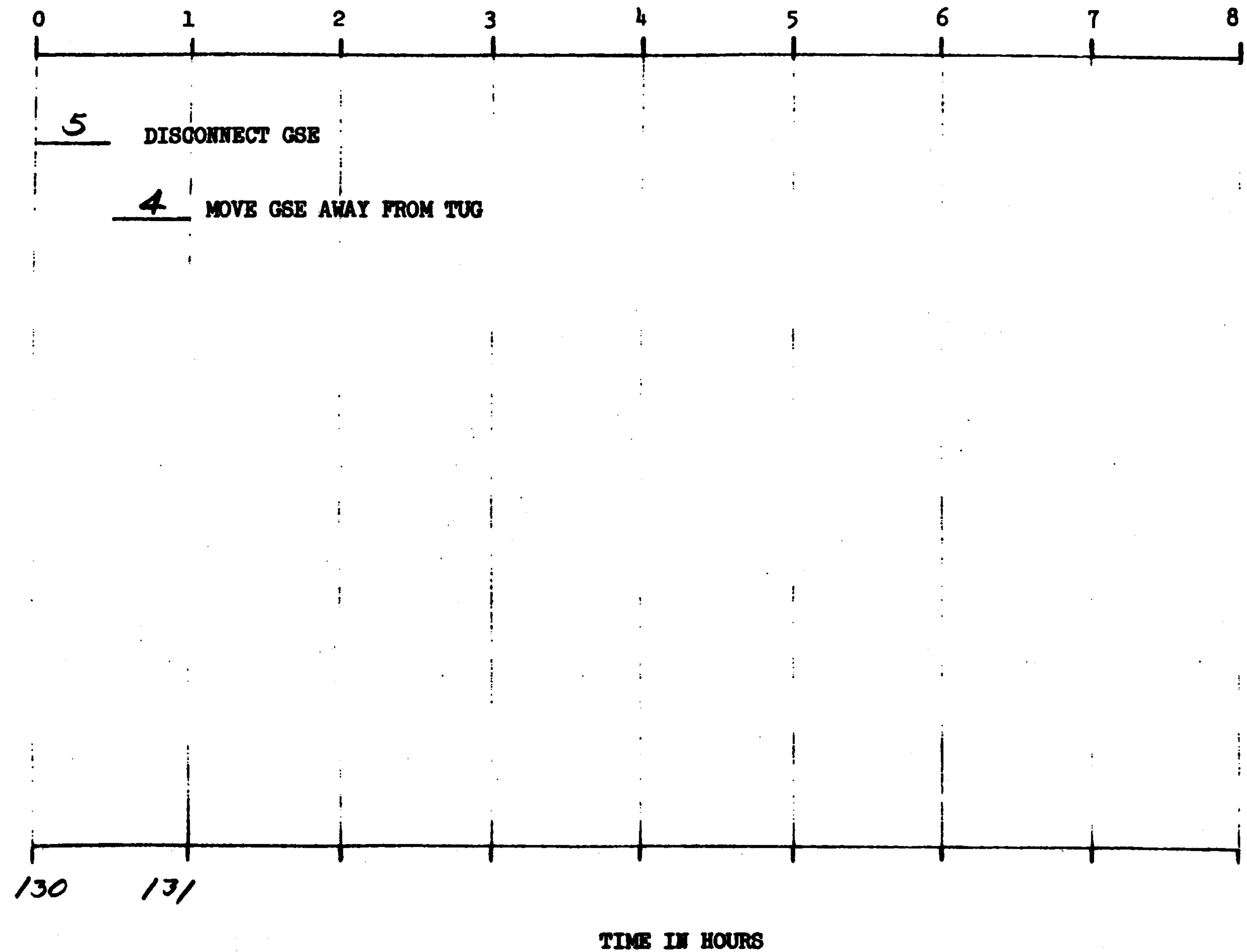
OPTION NUMBER 3F WTR	FUNCTION TITLE POST M&R VERIFICATION	FLOW BLOCK NO. 1.2.1



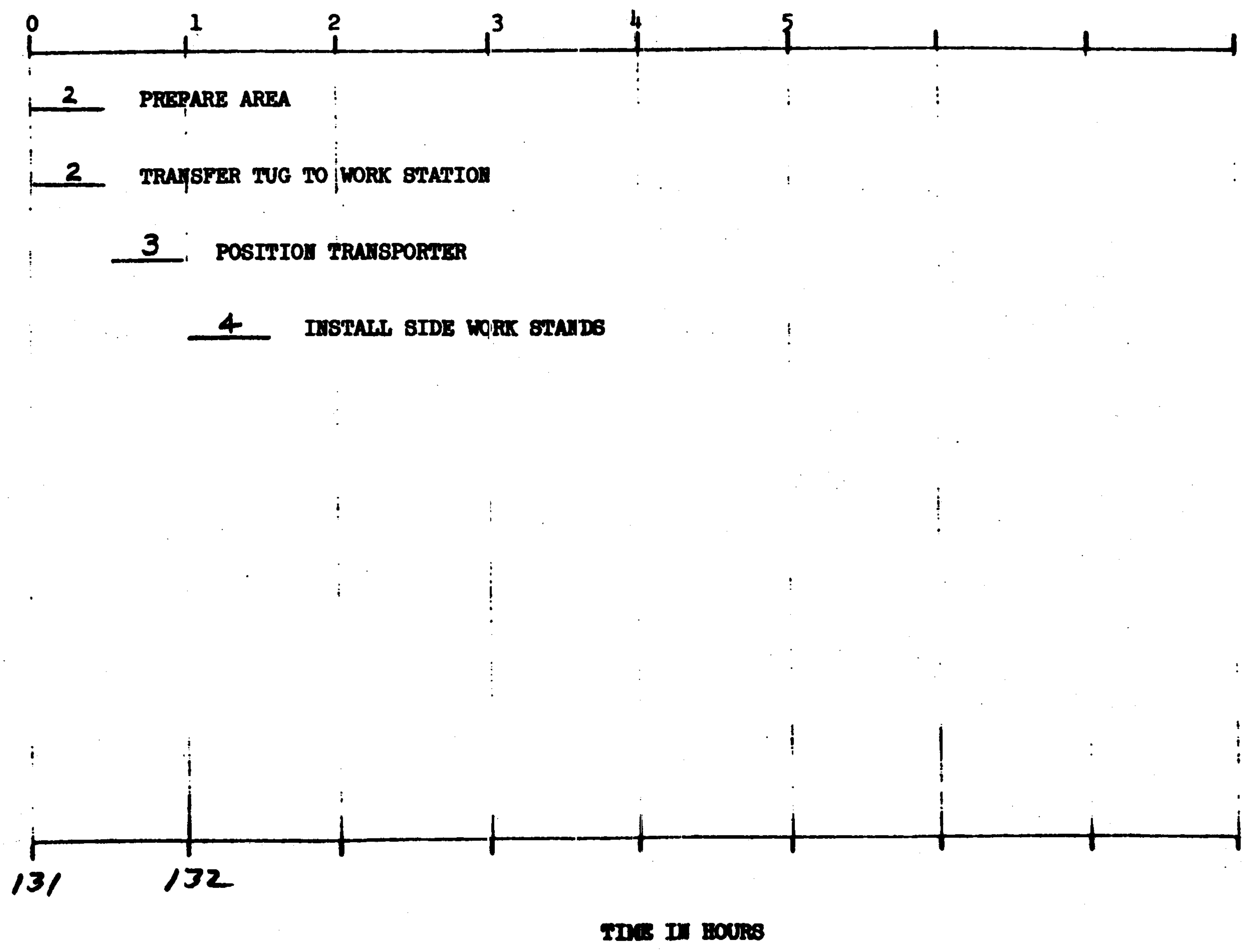
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F WTR	PERFORM POST M&R VERIFICATION - FSE	1.2.2



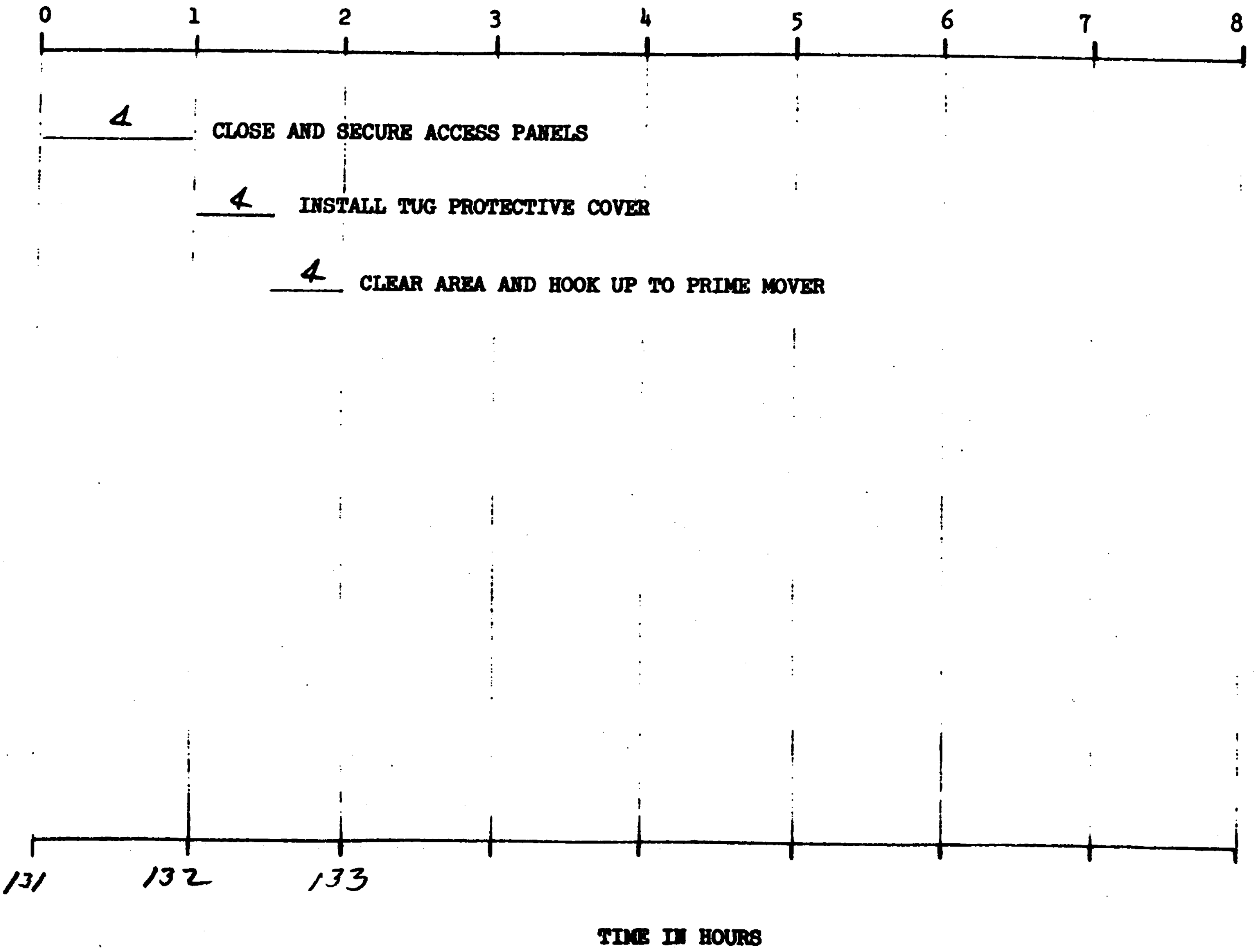
OPTION NUMBER 3F WTR	FUNCTION TITLE REMOVE M&R GSE	FLOW BLOCK NO. 1.1.14



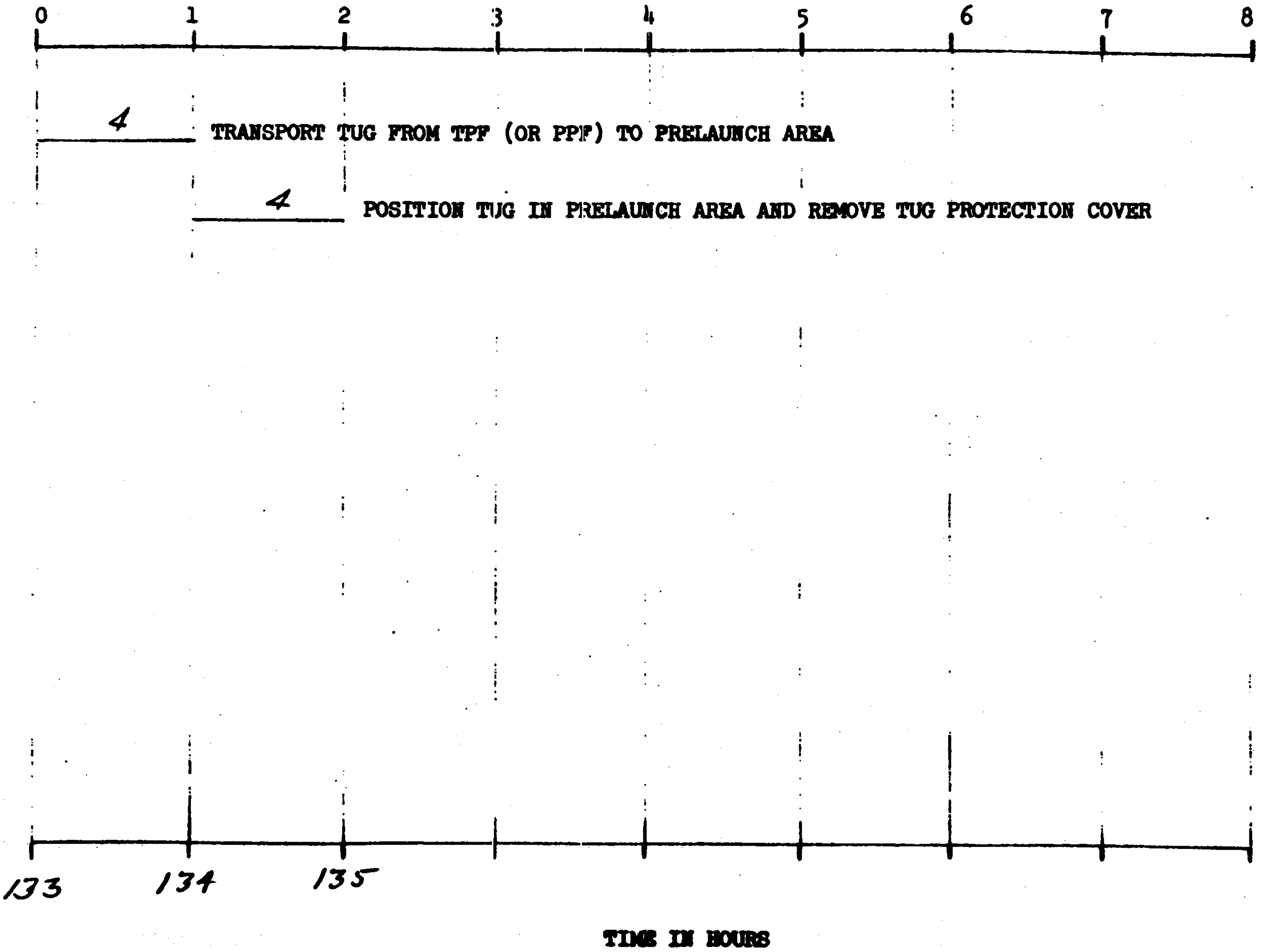
OPTION NUMBER 3F WTR	FUNCTION TITLE RECEIVE TUG FROM M&R	FLOW BLOCK NO. 2.1.2



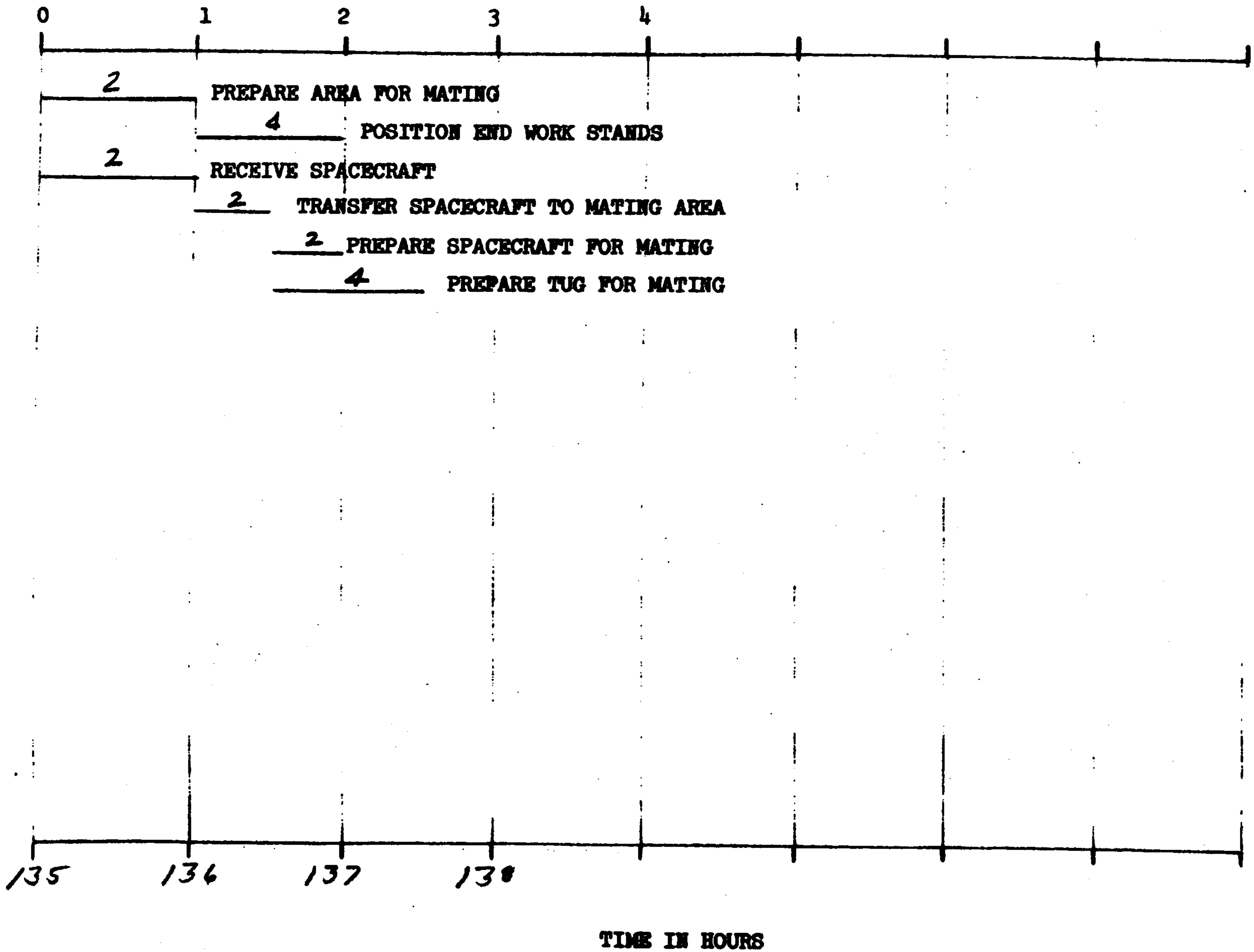
OPTION NUMBER	3F WTR	FUNCTION TITLE	PREPARE FOR TRANSPORT	FLOW BLOCK NO.	1.1.2 1



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F WTR	TRANSFER TO PRELAUNCH	1.1.2 6

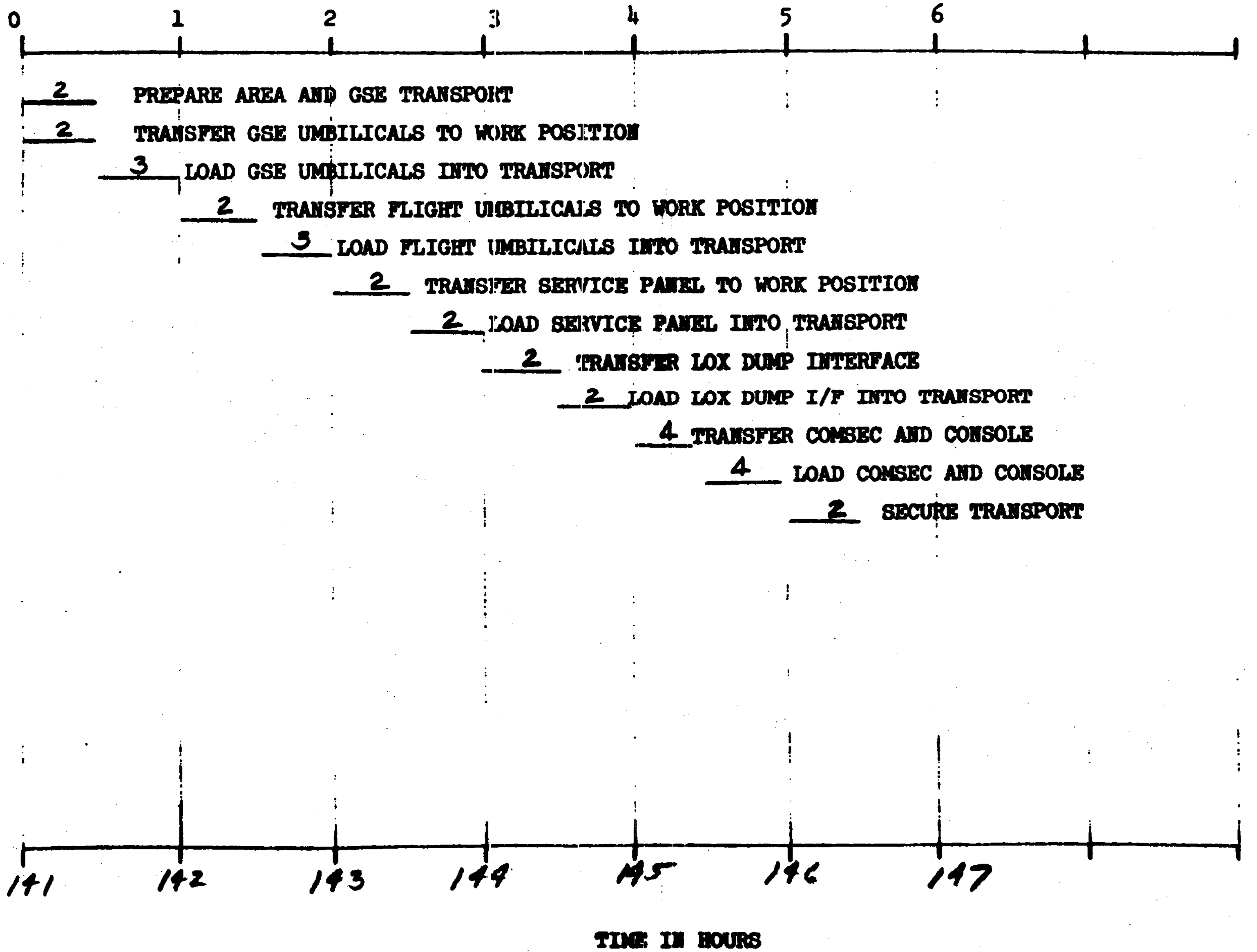


OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F WTR	PREPARE TUG FOR SPACECRAFT	2.2.2.a

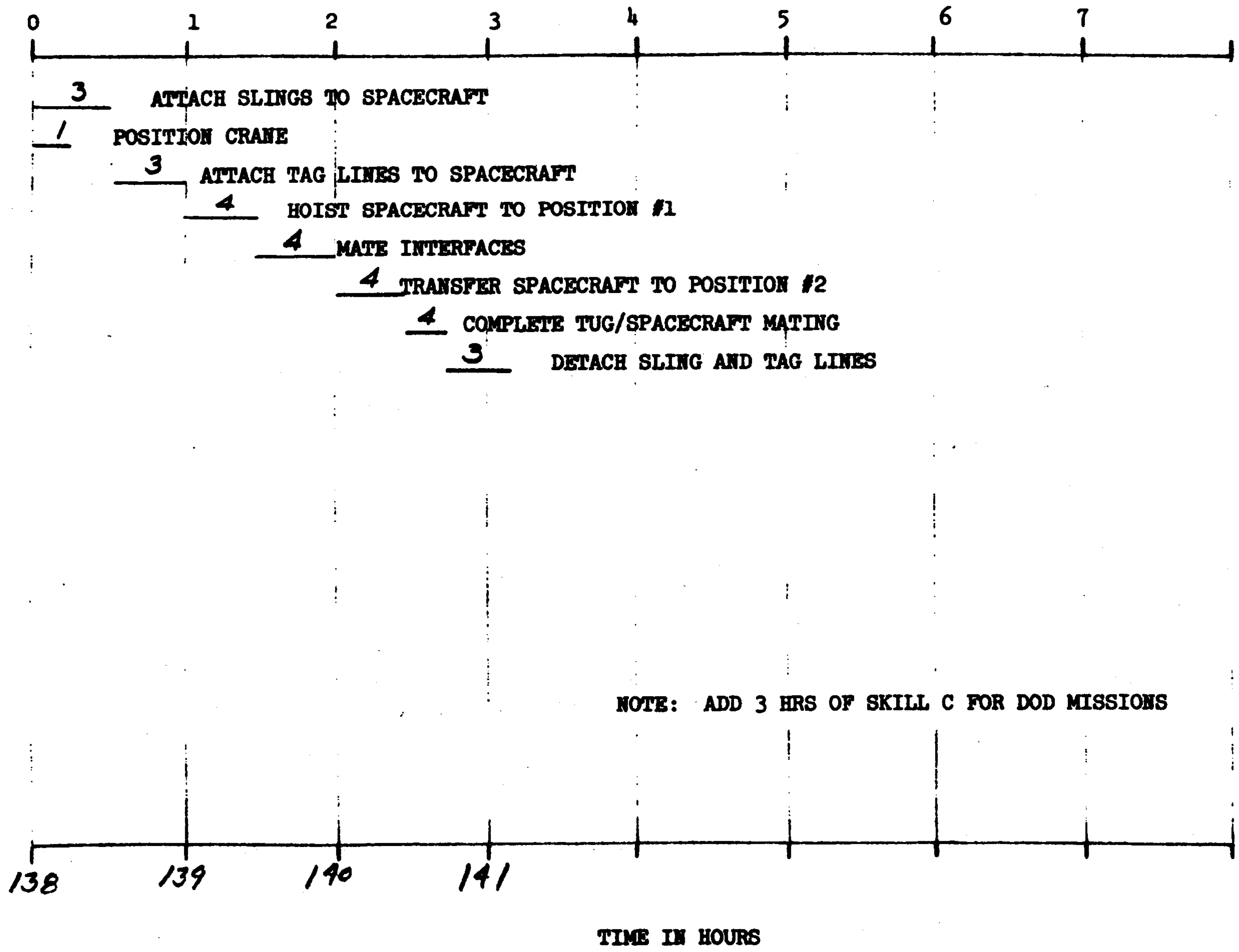


NOTE: NO KICK STAGE

OPTION NUMBER 3F WTR	FUNCTION TITLE RECEIVE FSE FROM M&R	FLOW BLOCK NO. 2.1.1

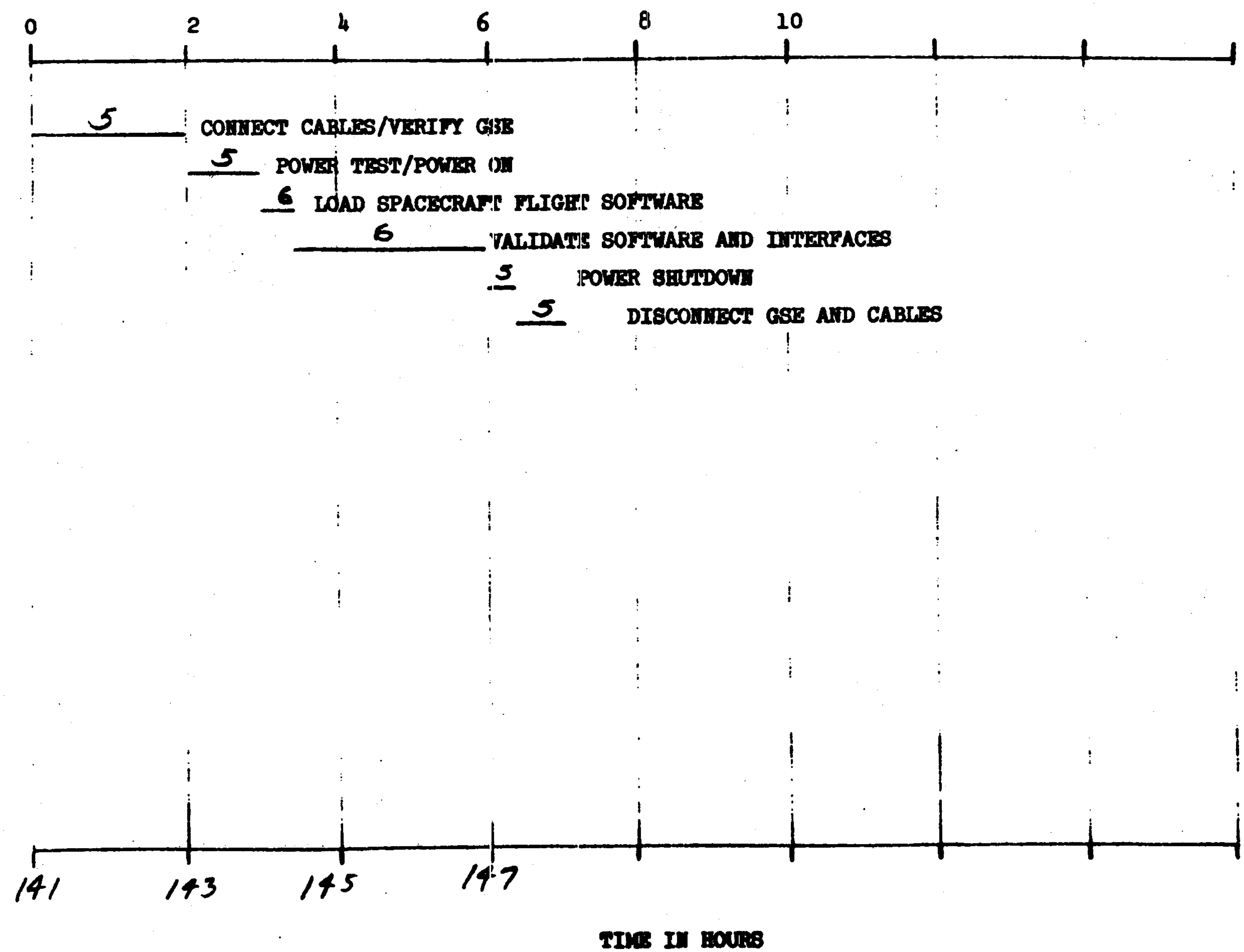


OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F WTR	MATE TUG AND SPACECRAFT	2.2.3

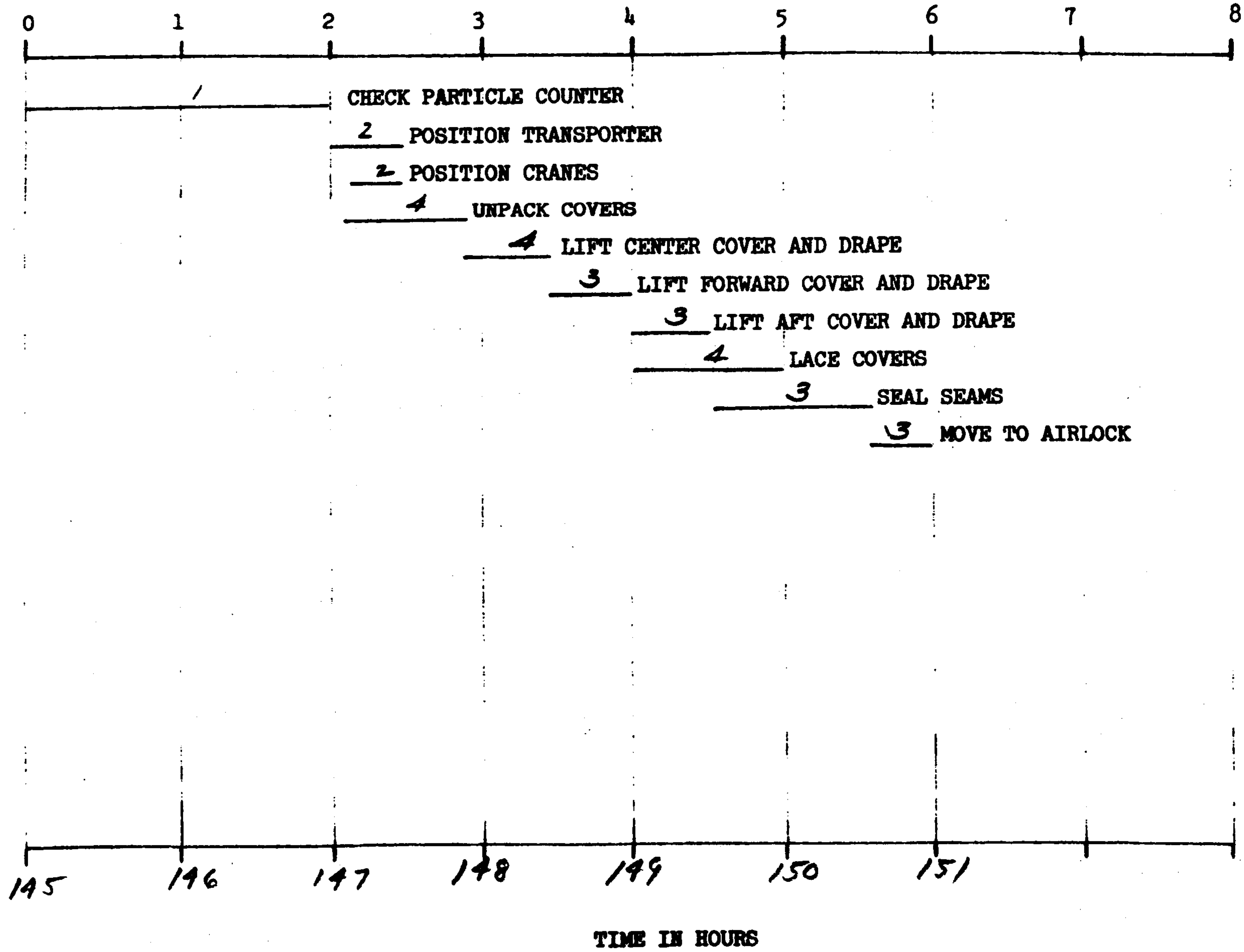


NOTE: ADD 3 HRS OF SKILL C FOR DOD MISSIONS

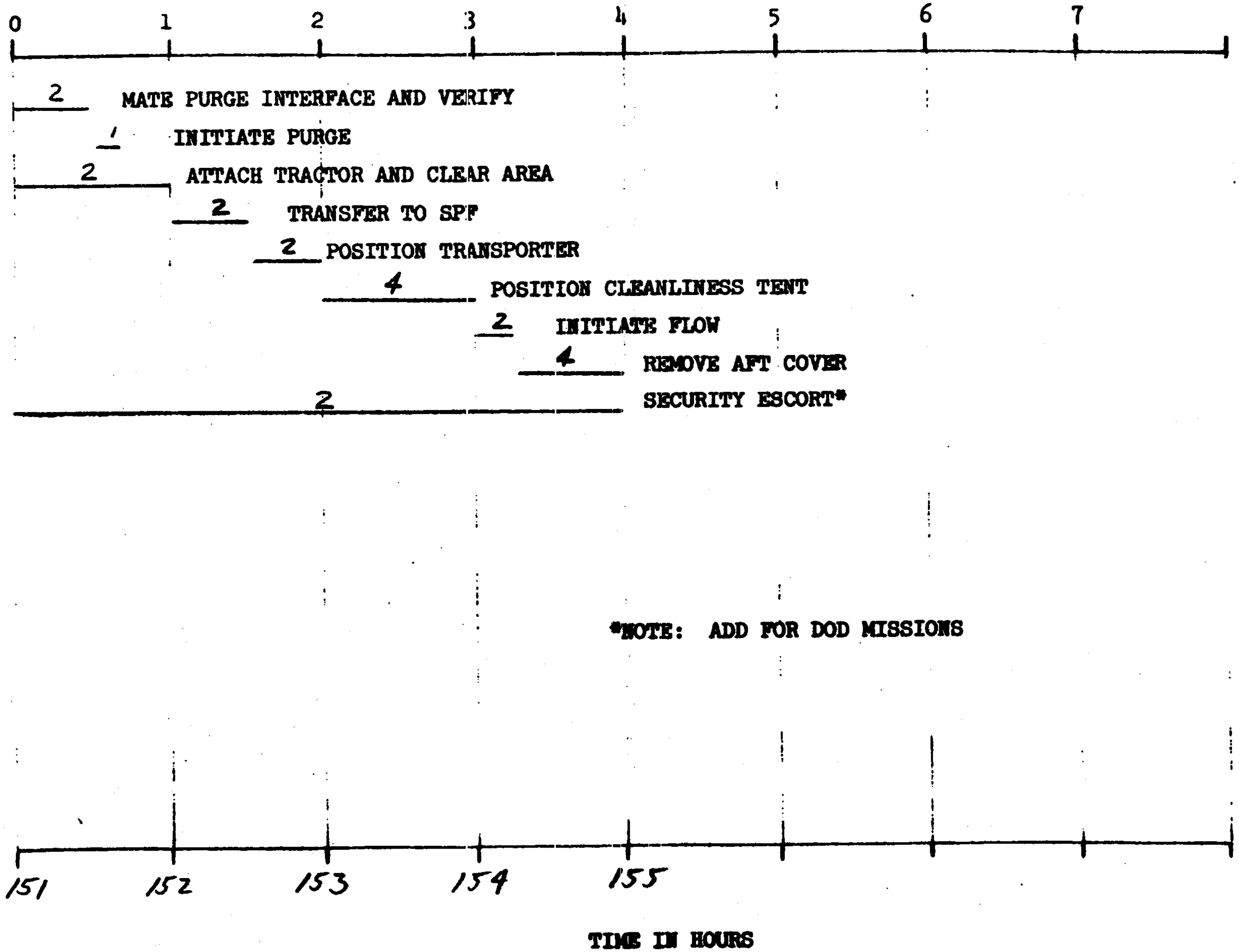
OPTION NUMBER 3F WTR	FUNCTION TITLE VERIFY TUG-TO-SPACECRAFT INTERFACES	FLOW BLOCK NO. 2.2.4



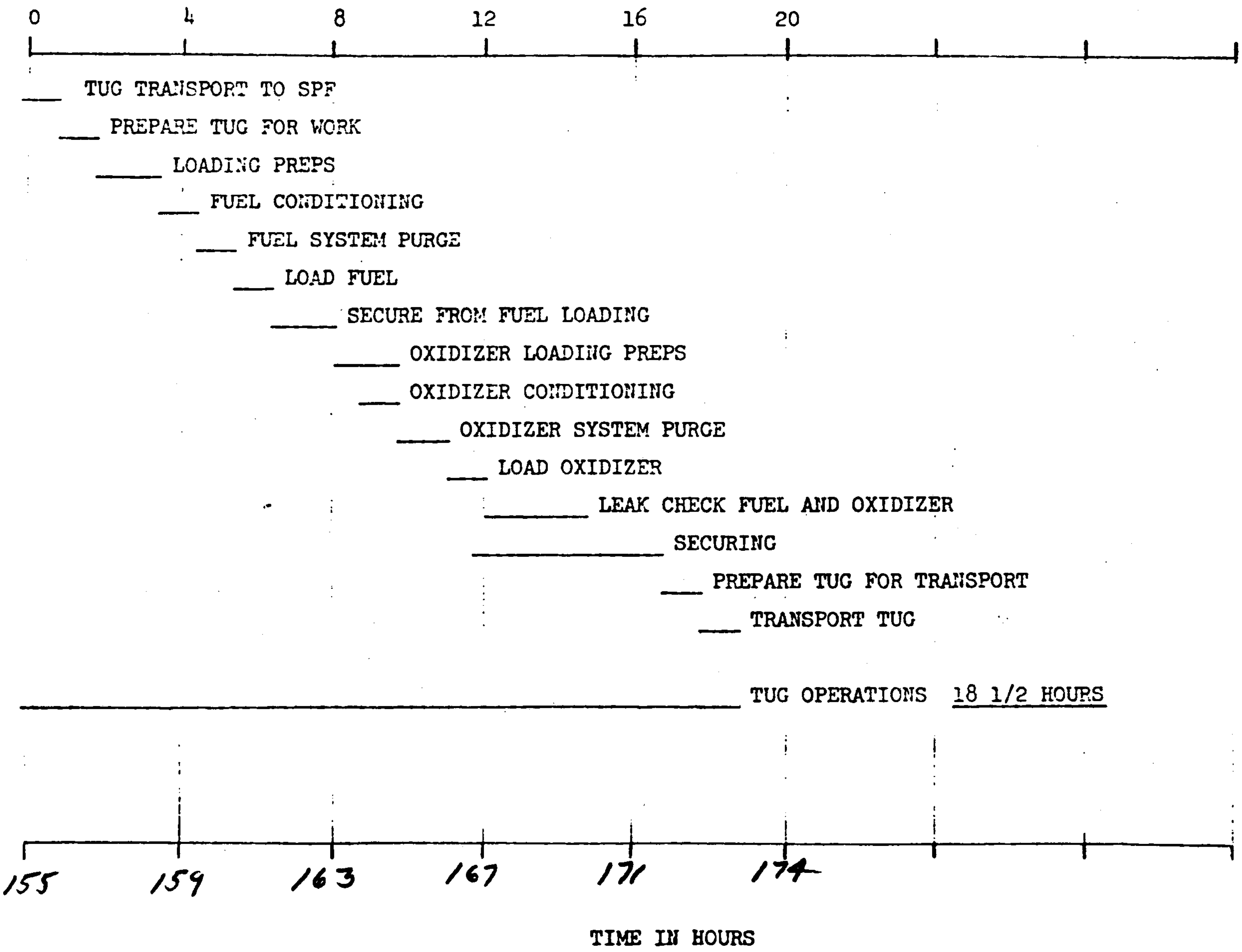
OPTION NUMBER 3F WTR	FUNCTION TITLE VERIFY CLEANLINESS	FLOW BLOCK NO. 2.2.5



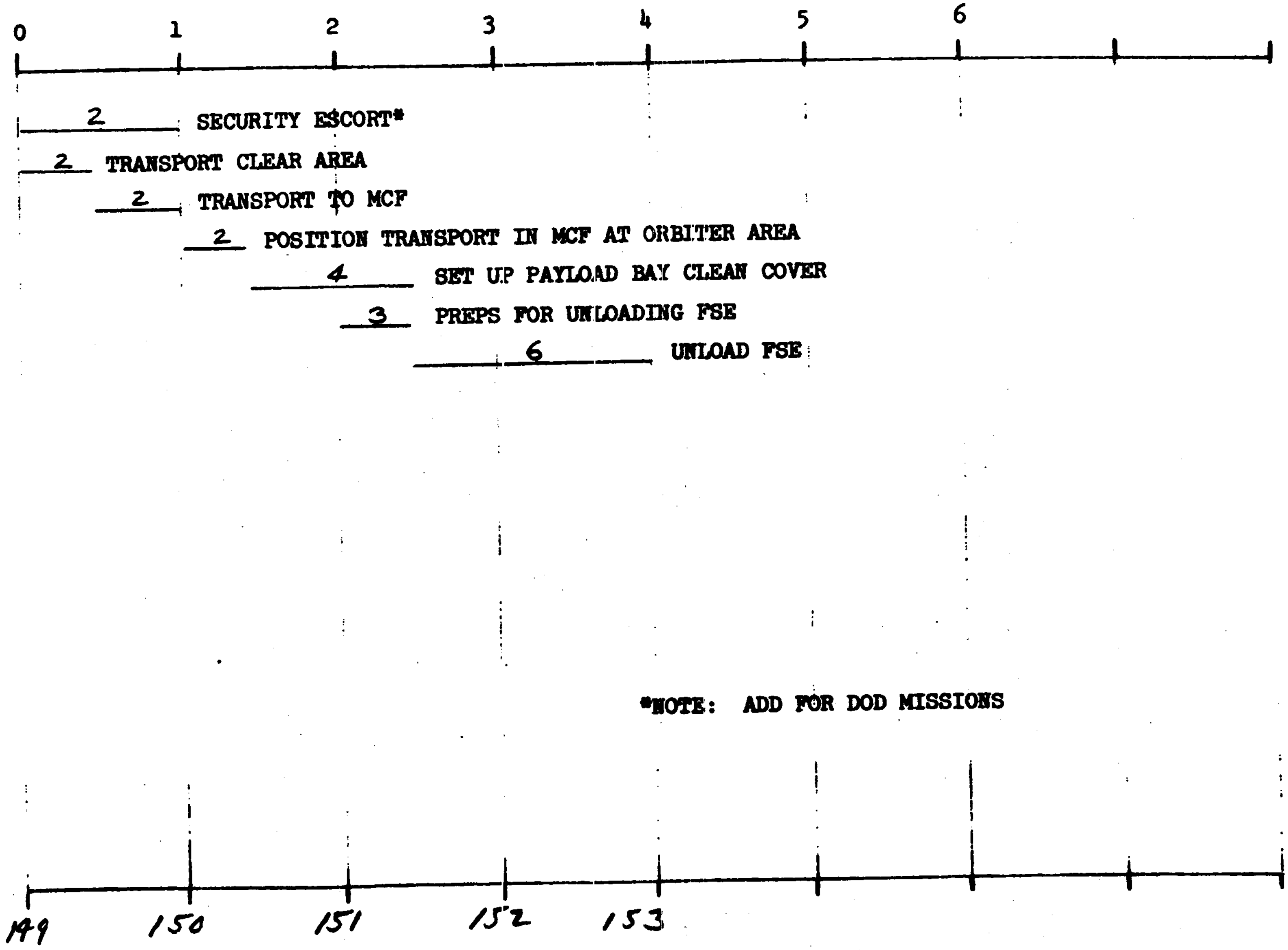
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F WTR	TRANSFER PAYLOAD TO SPF	2.1.5



OPTION NUMBER 3F WTR	FUNCTION TITLE BIPROPELLANT APS LOADING AT SPF INTEGRAL SYSTEM	FLOW BLOCK NO. 2.1.8



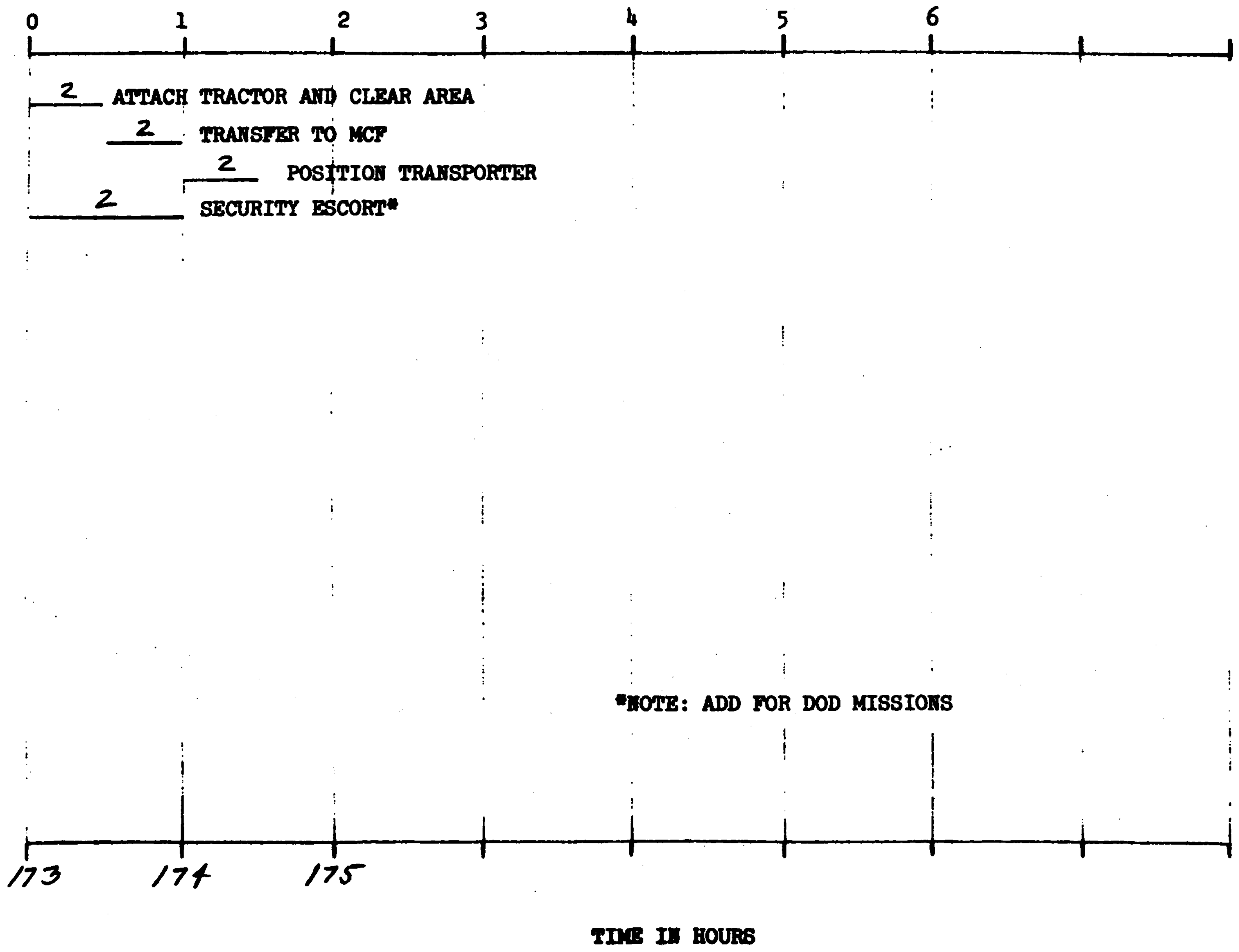
OPTION NUMBER 3F WTR	FUNCTION TITLE TRANSFER FSE TO MCF	FLOW BLOCK NO. 2.3.1



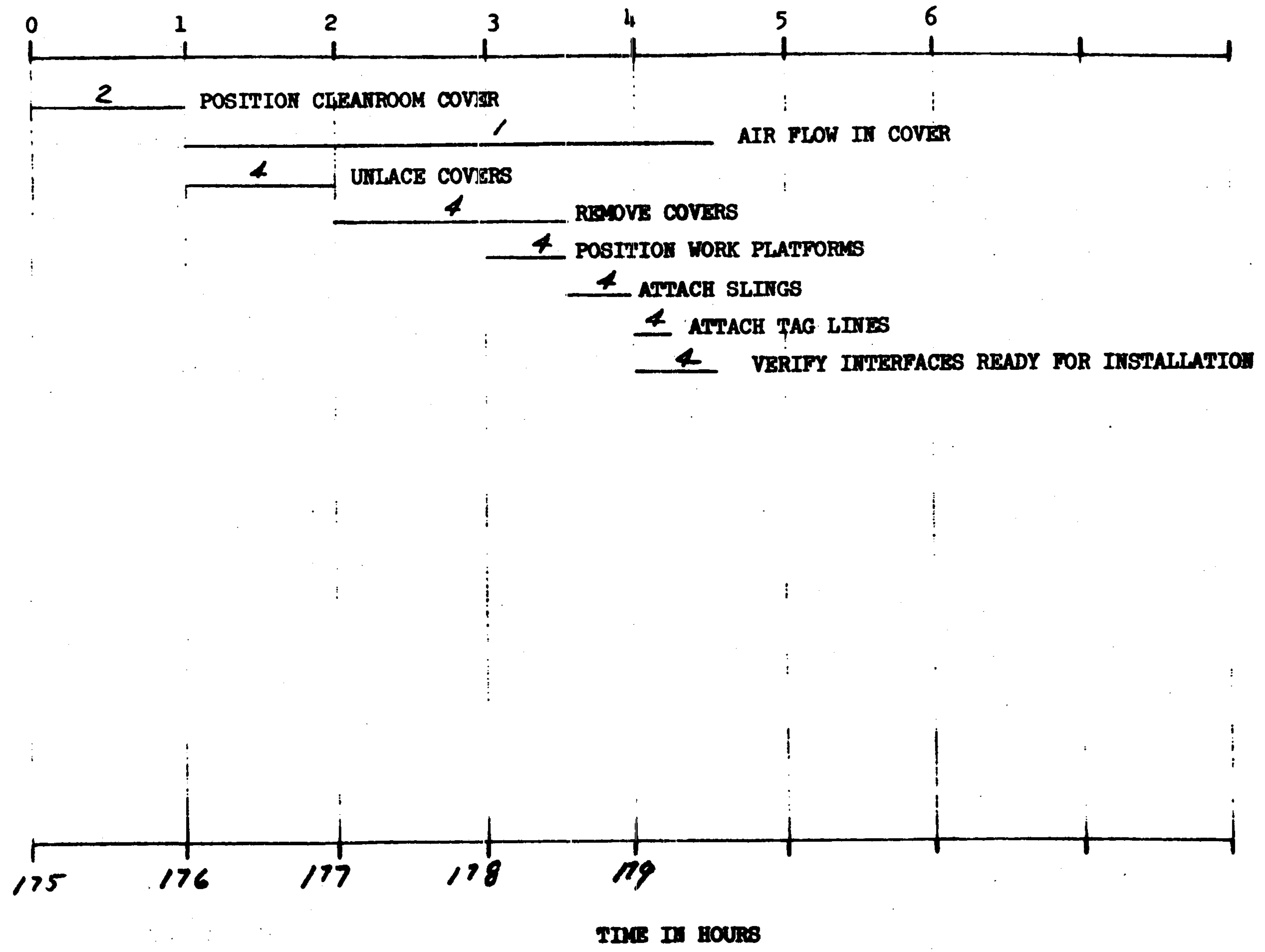
*NOTE: ADD FOR DOD MISSIONS

TIME IN HOURS

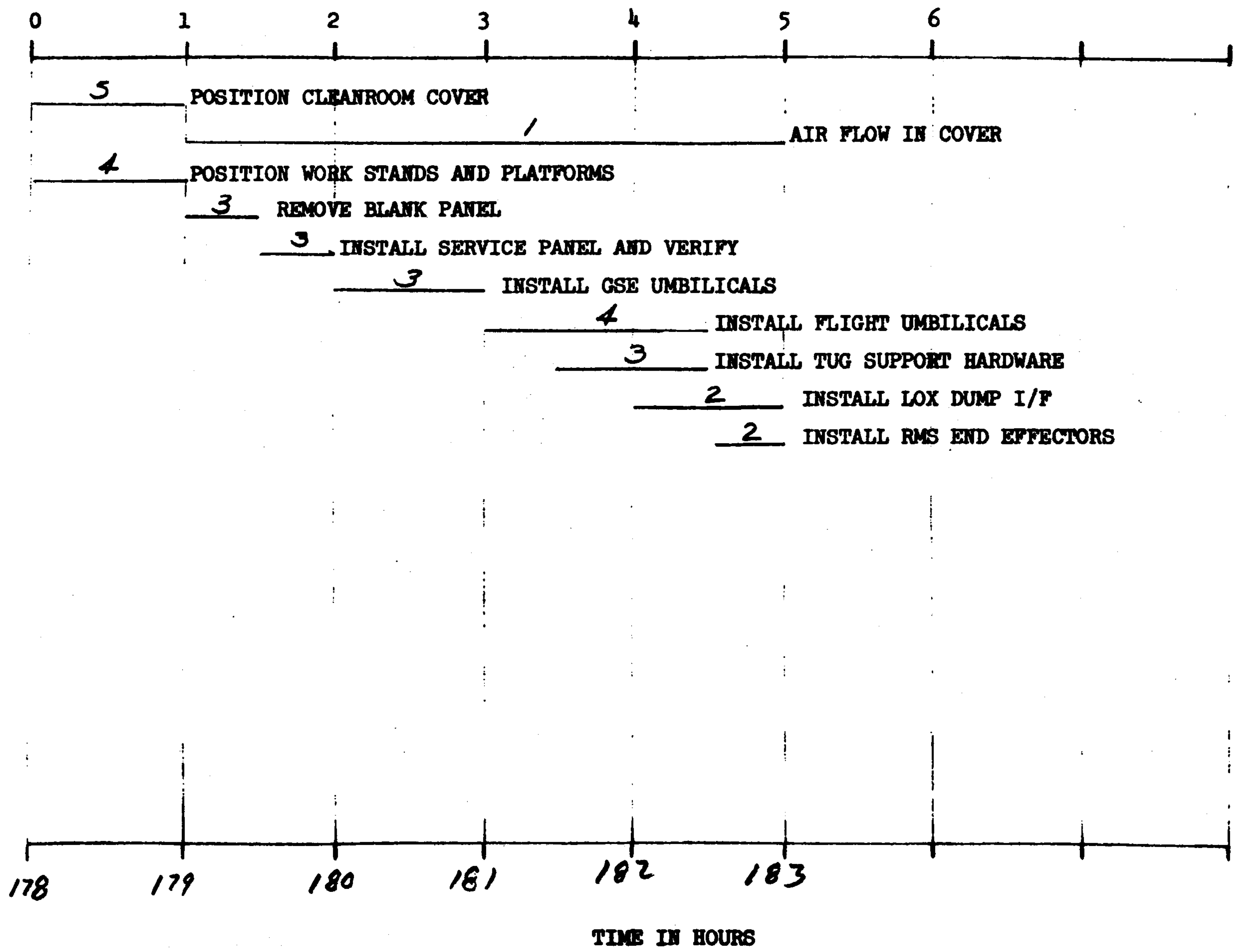
OPTION NUMBER 3F WTR	FUNCTION TITLE TRANSFER PAYLOAD TO MCF	FLOW BLOCK NO. 2.3.4



OPTION NUMBER 3F WTR	FUNCTION TITLE PAYLOAD INSTALLATION PREPS	FLOW BLOCK NO. 2.3.6



OPTION NUMBER 3F WTR	FUNCTION TITLE INSTALL FSE IN PAYLOAD BAY	FLOW BLOCK NO. 2.3.2.2



OPTION NUMBER 3F WTR	FUNCTION TITLE PAYLOAD INSTALLATION MCF	FLOW BLOCK NO. 2.3.7

0 2 4 6 8

1 AIR FLOW IN COVER

2 POSITION CRANES

4 TRANSPORTER RELEASE

2 HOIST PAYLOAD TO POSITION #1

2 LOWER TO POSITION #2

2 LOWER AFT SLING TO POSITION #3

4 MATE GSE UMBILICALS TO TUG

2 MATE LOX DUMP INTERFACE

4 MATE FLIGHT UMBILICALS TO TUG

4 VERIFY INTERFACE CONTINUITY

2 LOWER TO POSITION #4

5 MATE AFT PHYSICAL/MECHANICAL I/F's

2 LOWER TO POSITION #5

.5 MATE FORWARD PHYS./MECH. I/F's

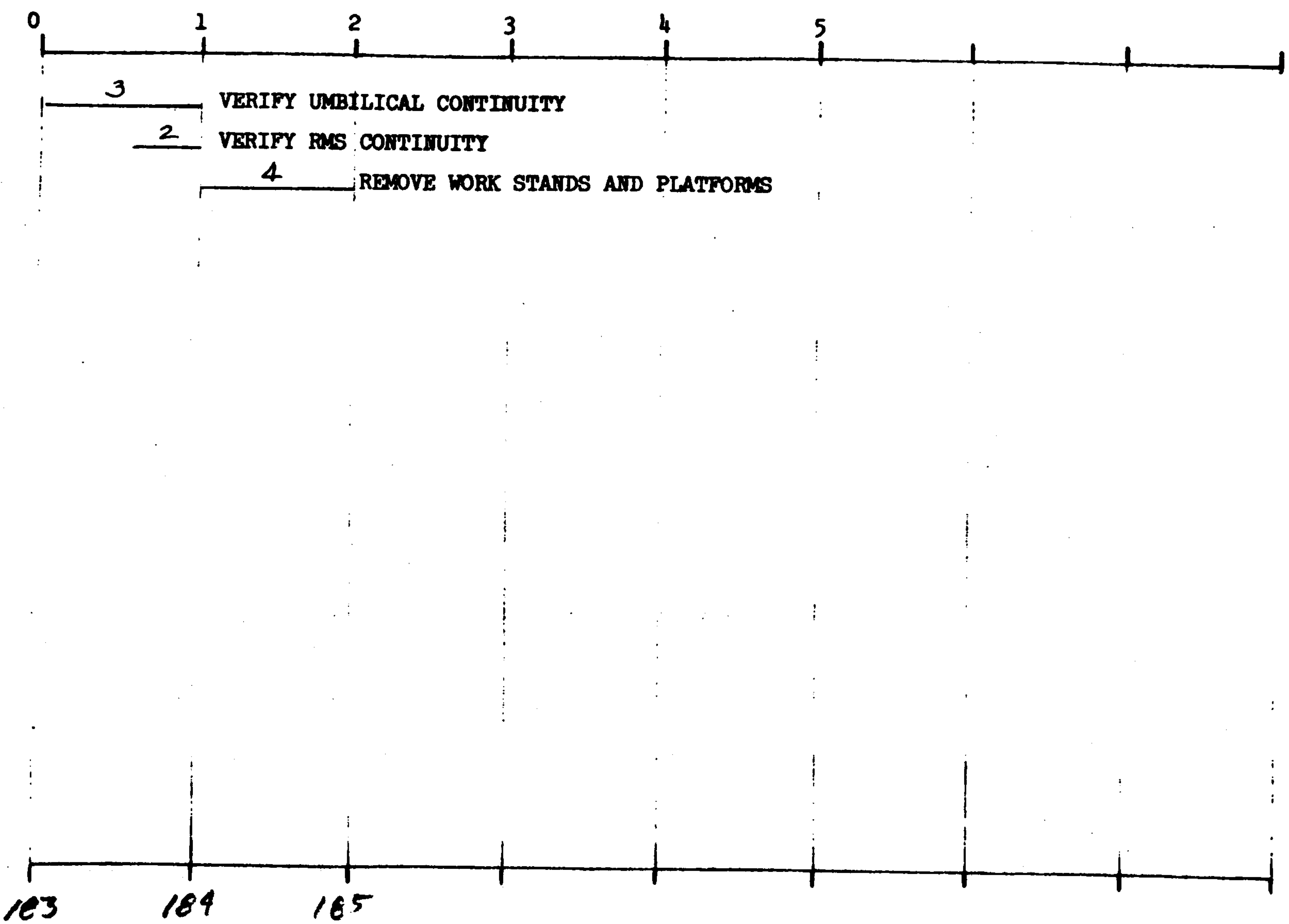
0 CLOSE PAYLOAD BAY DOORS

4 REMOVE TENT

183 185 187 189 191

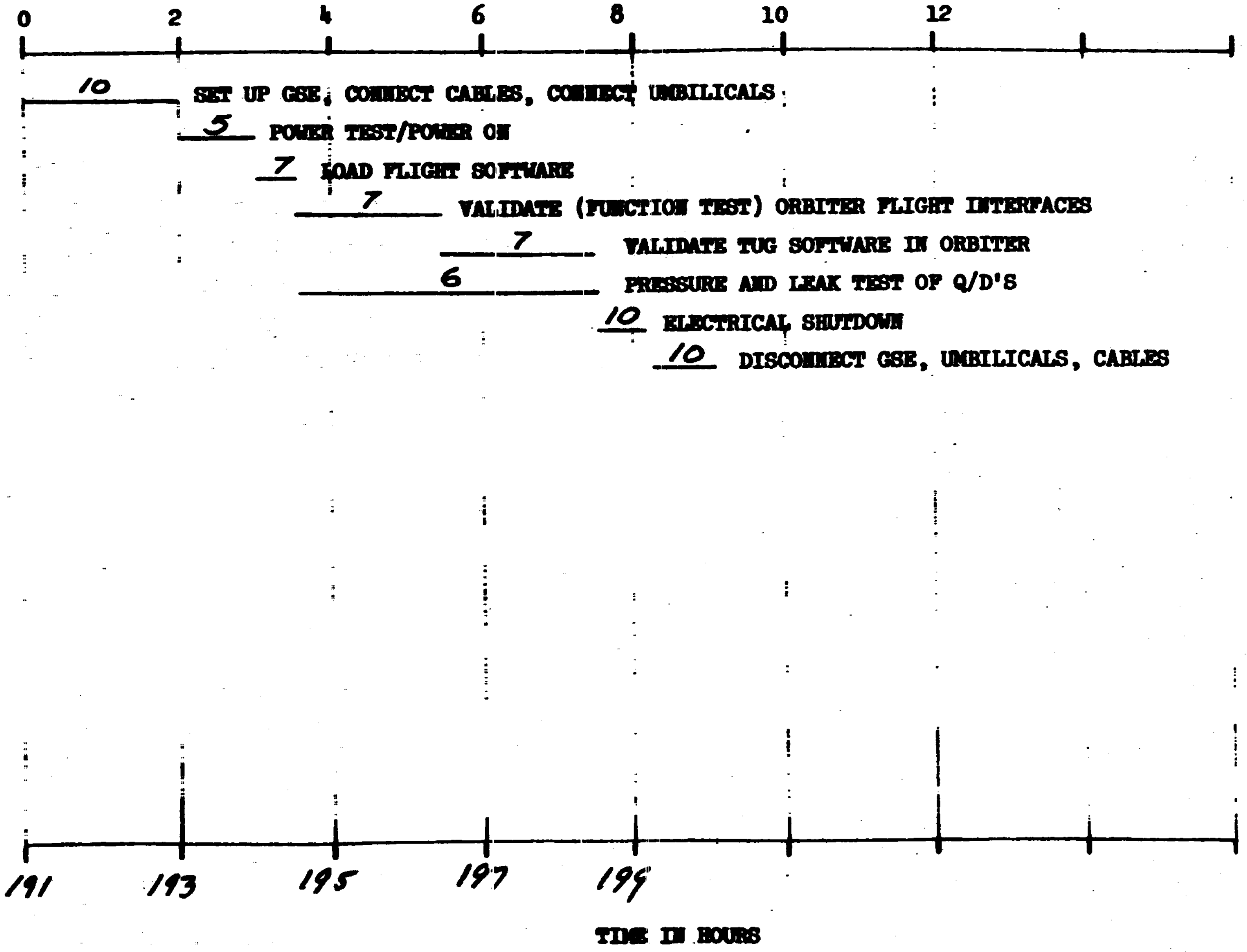
TIME IN HOURS

OPTION NUMBER	3F WTR	FUNCTION TITLE	VERIFY FSE INTERFACES	FLOW BLOCK NO.	2.3.3

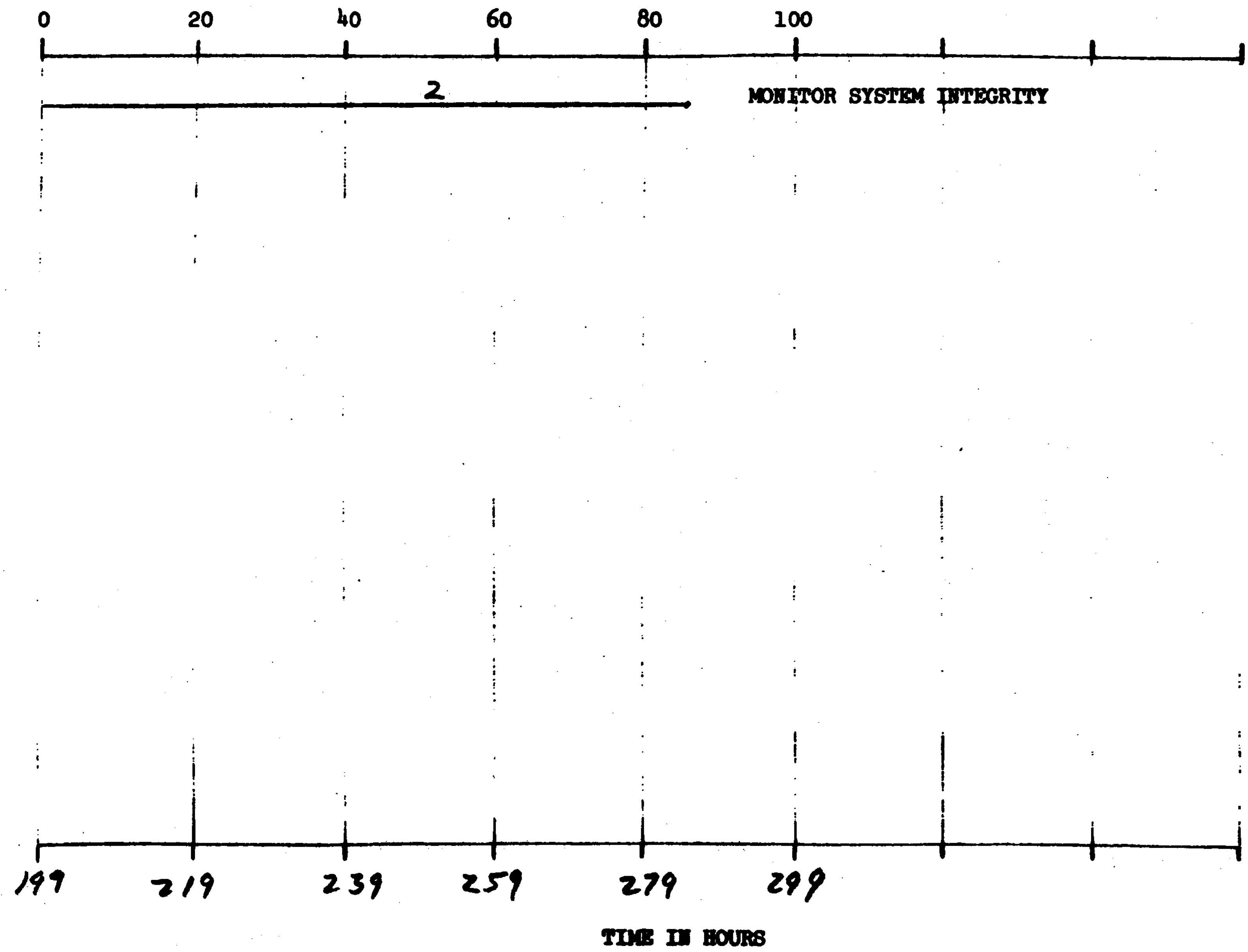


TIME IN HOURS

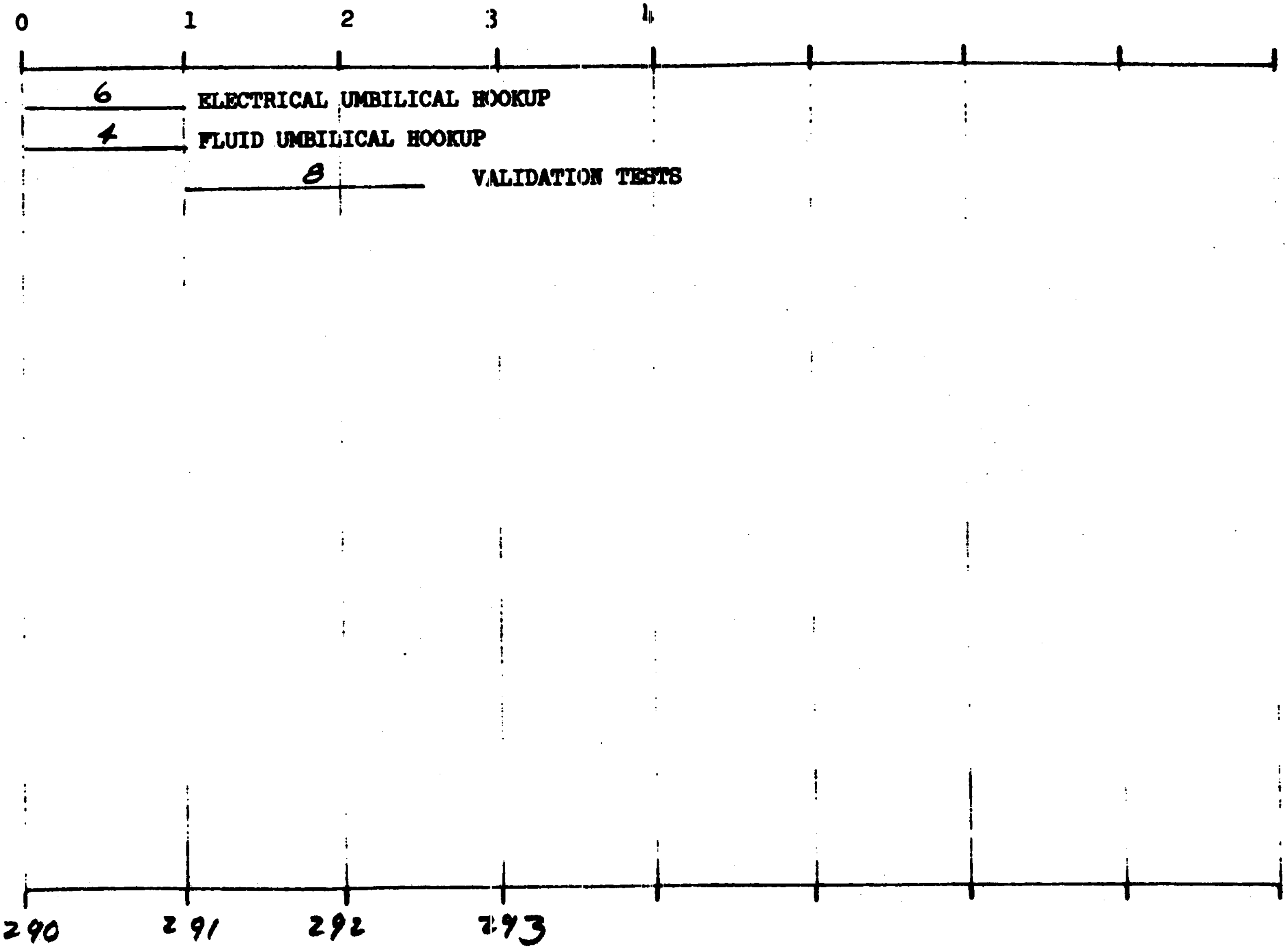
OPTION NUMBER	FUNCTION TITLE VERIFY PAYLOAD-TO-SHUTTLE INTERFACES	FLOW BLOCK NO. 2.3.9



OPTION NUMBER 3F WTR	FUNCTION TITLE MONITOR STORABLE ACPS	FLOW BLOCK NO. 2.4.1.a



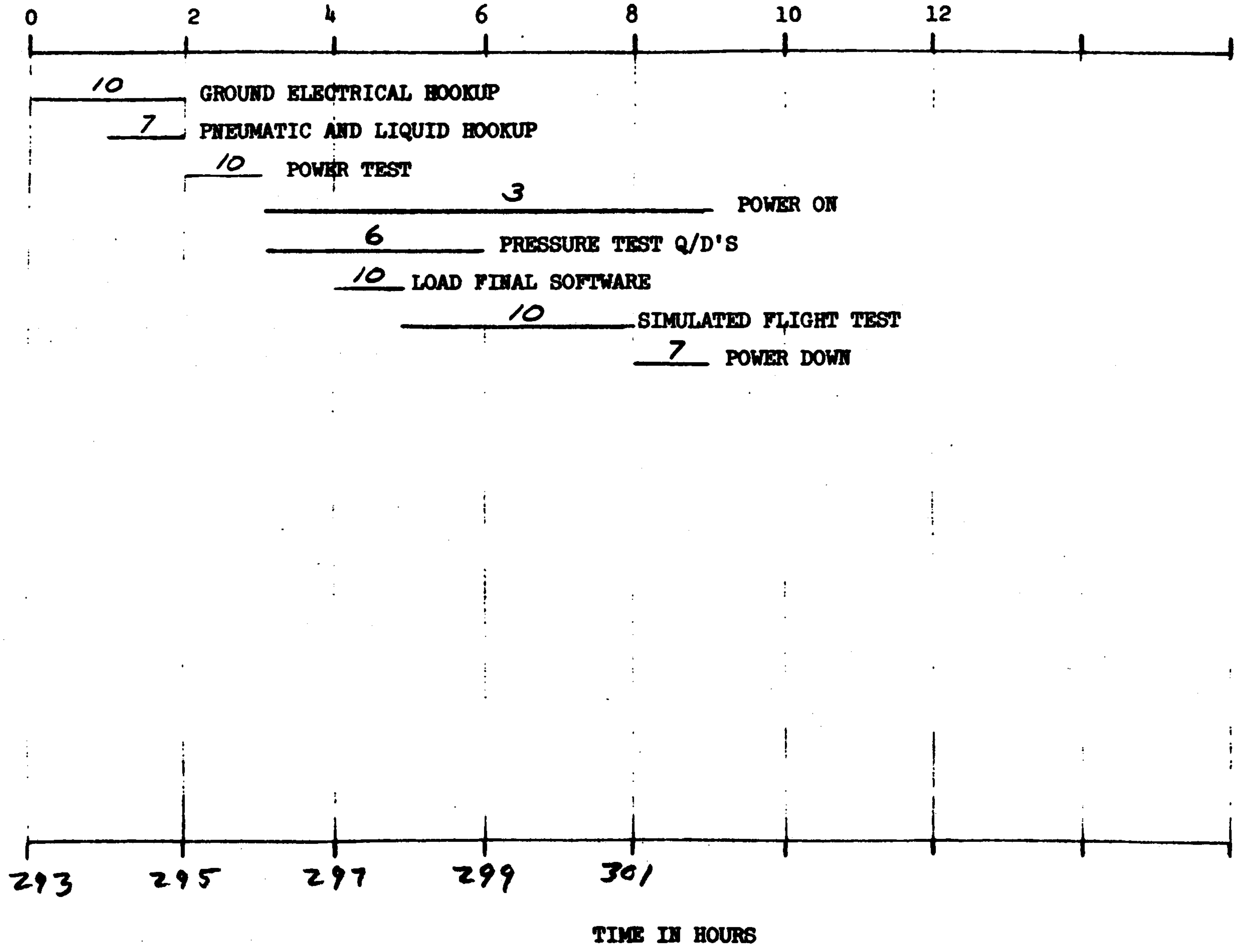
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F WTR	TUG SERVICE AT PAD (NON-CRYOS)	2.4.2.a



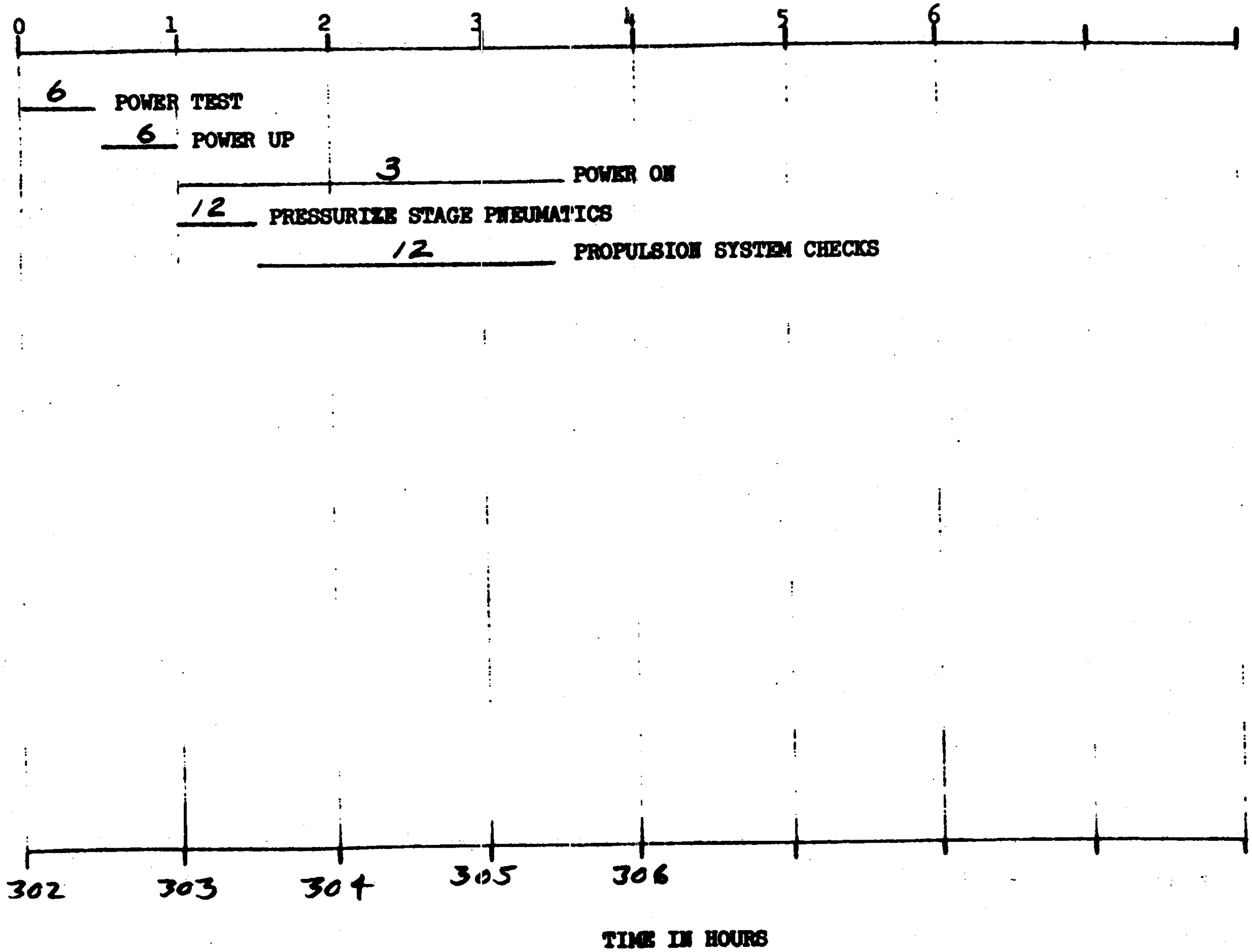
TIME IN HOURS

UMBILICAL HOOKUP

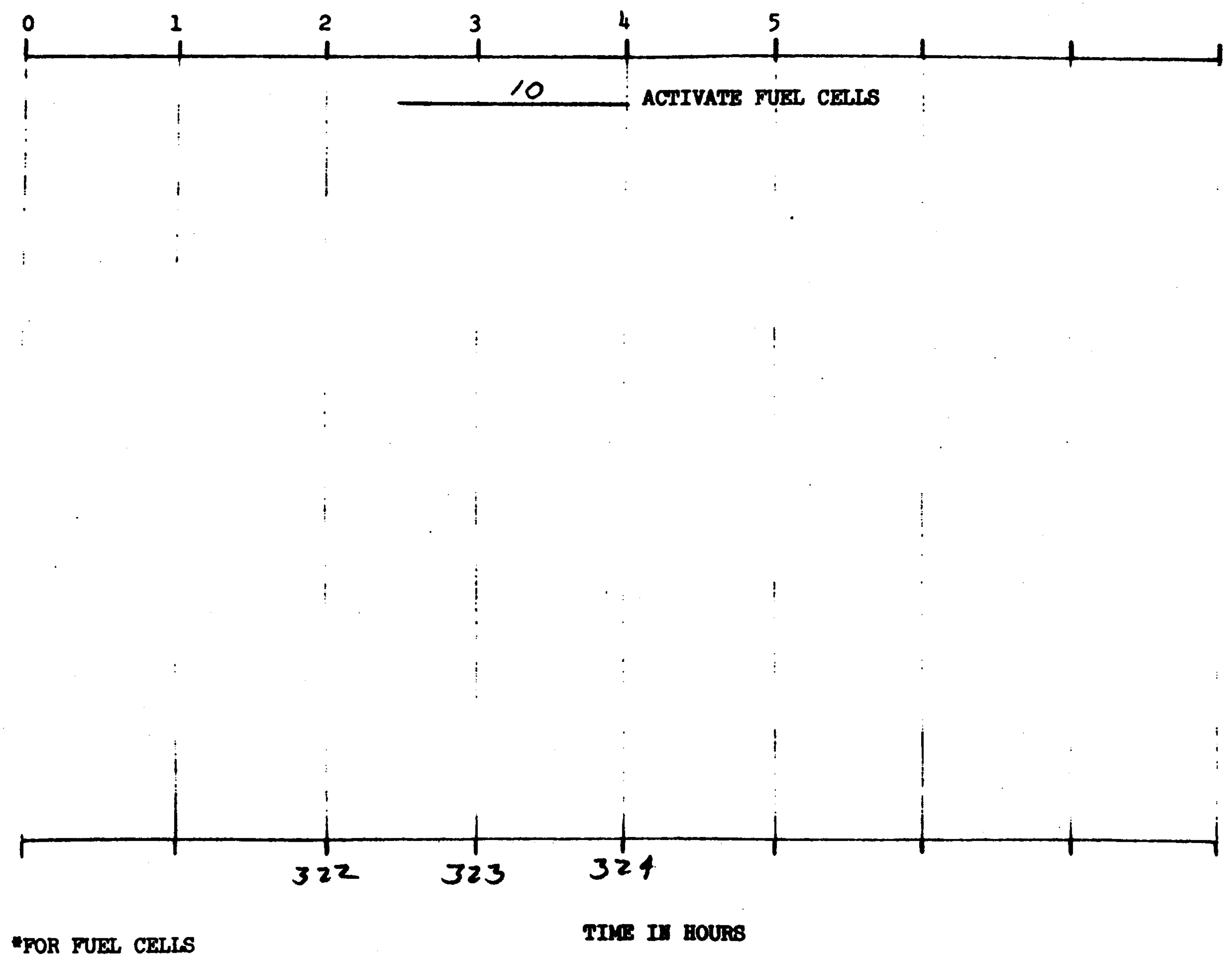
OPTION NUMBER 3F WTR	FUNCTION TITLE ORBITER/PAYLOAD INTEGRATION SYSTEM TEST	FLOW BLOCK NO. 2.4.1



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F WTR	TUG SERVICE AT PAD (NON-CRYO)	2.4.2.b

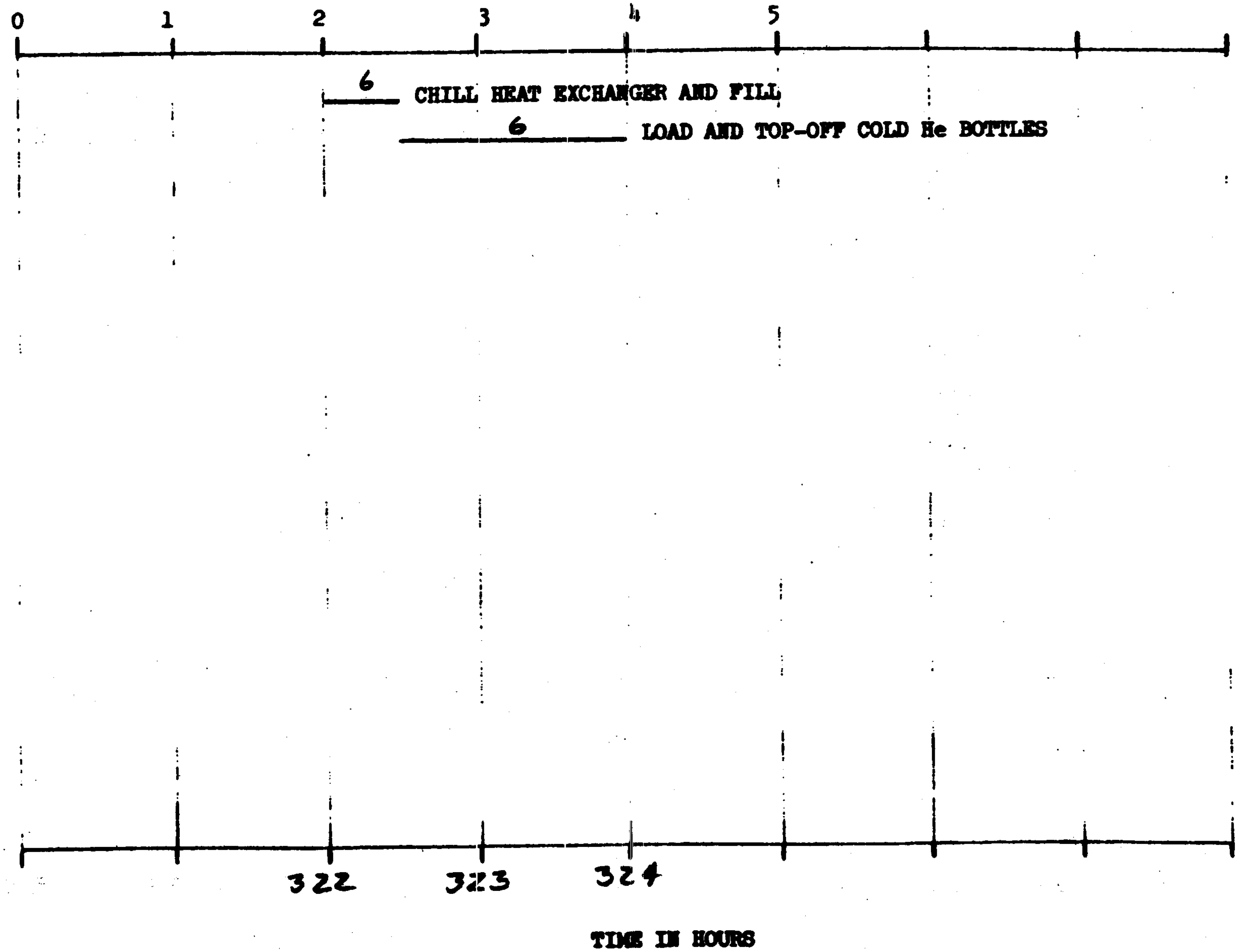


OPTION NUMBER	3F WTR	FUNCTION TITLE	TUG SERVICE AT PAD (CRYO'S)*	FLOW BLOCK NO.	2.4.3.a



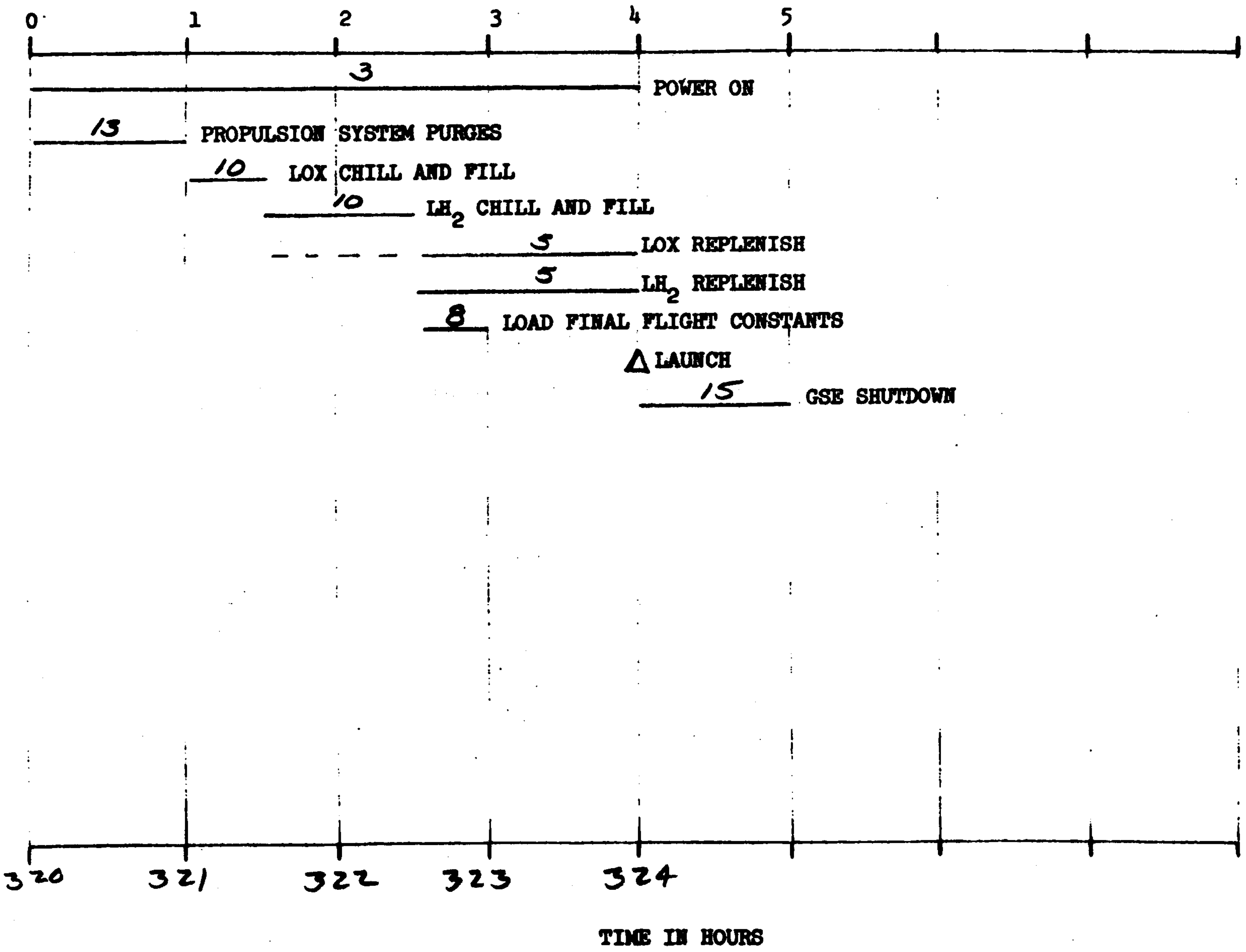
*FOR FUEL CELLS

OPTION NUMBER 3F W/R	FUNCTION TITLE TUG SERVICE AT PAD (CRYO'S)*	FLOW BLOCK NO. 2.4.3.b

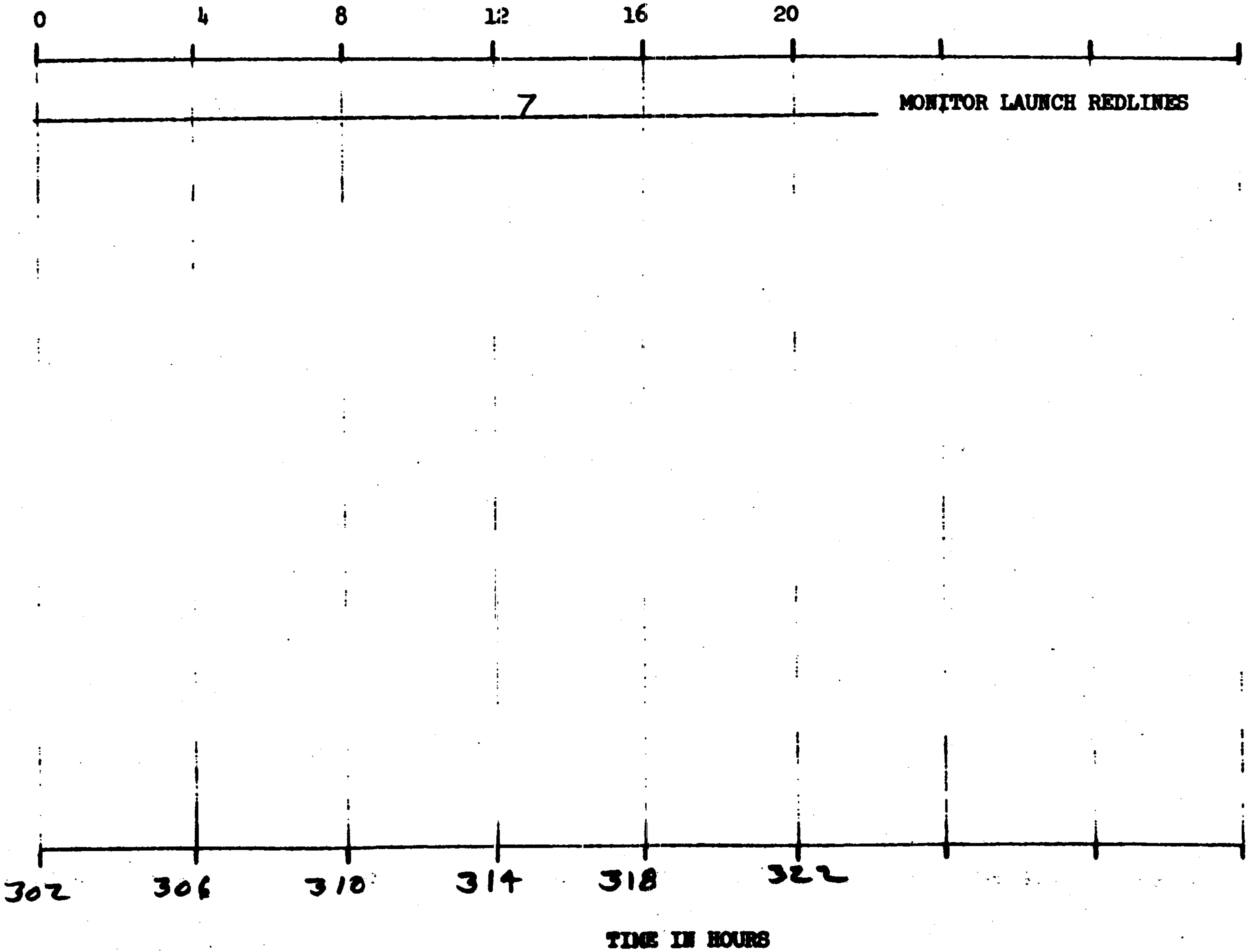


*FOR COLD HE PRESS. SYSTEM

OPTION NUMBER	3F WTR	FUNCTION TITLE	TUG SERVICE AT PAD (CRYO'S)	FLOW BLOCK NO.	2.4.3



OPTION NUMBER 3F WTR	FUNCTION TITLE SUBSYSTEM MONITORING AT PAD	FLOW BLOCK NO. 2.4.4



TASK TIMELINES

FOR

THE CRYOGENIC TUG

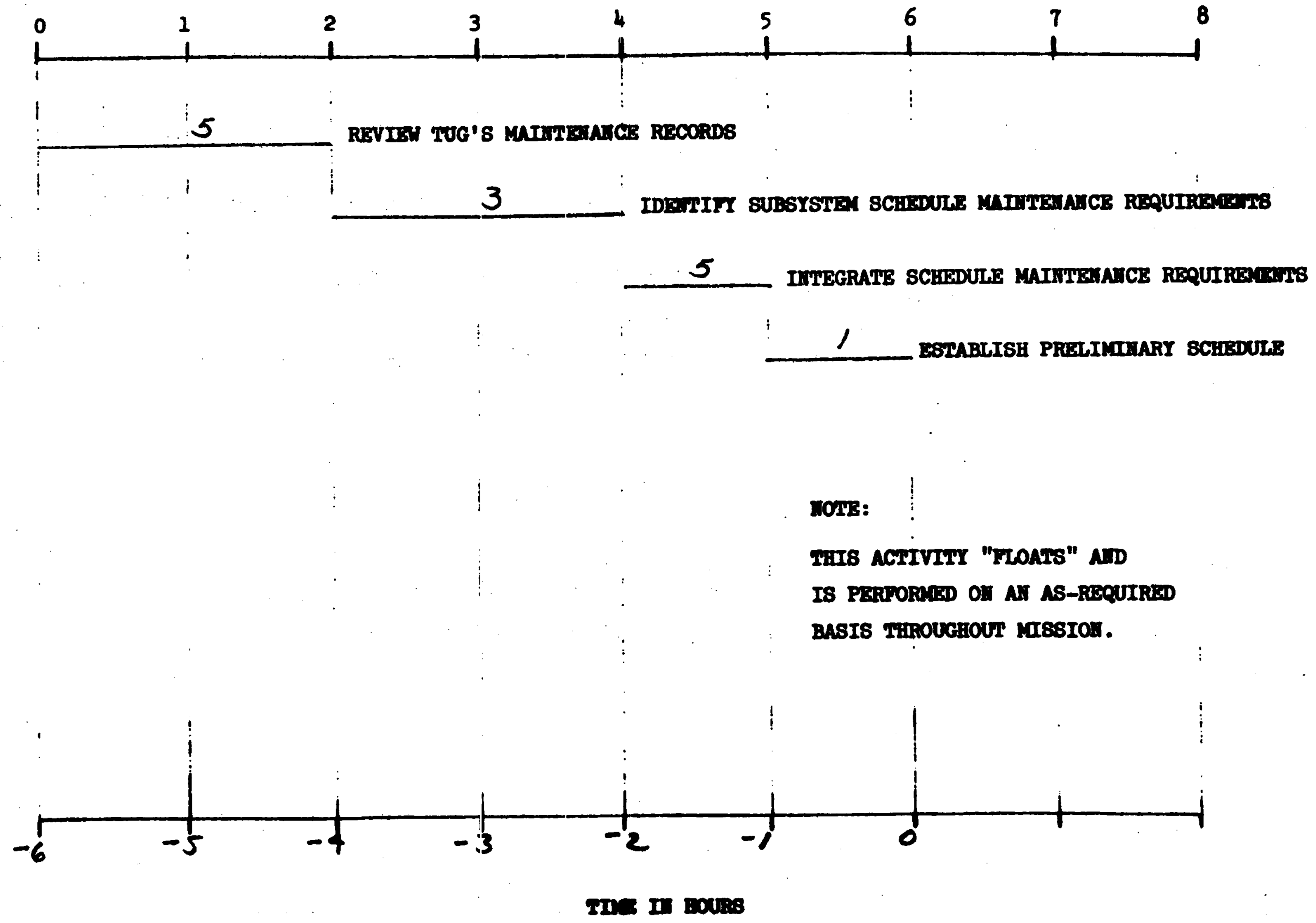
GROUND AND LAUNCH OPERATIONS

OPTION NO. 3I ETR

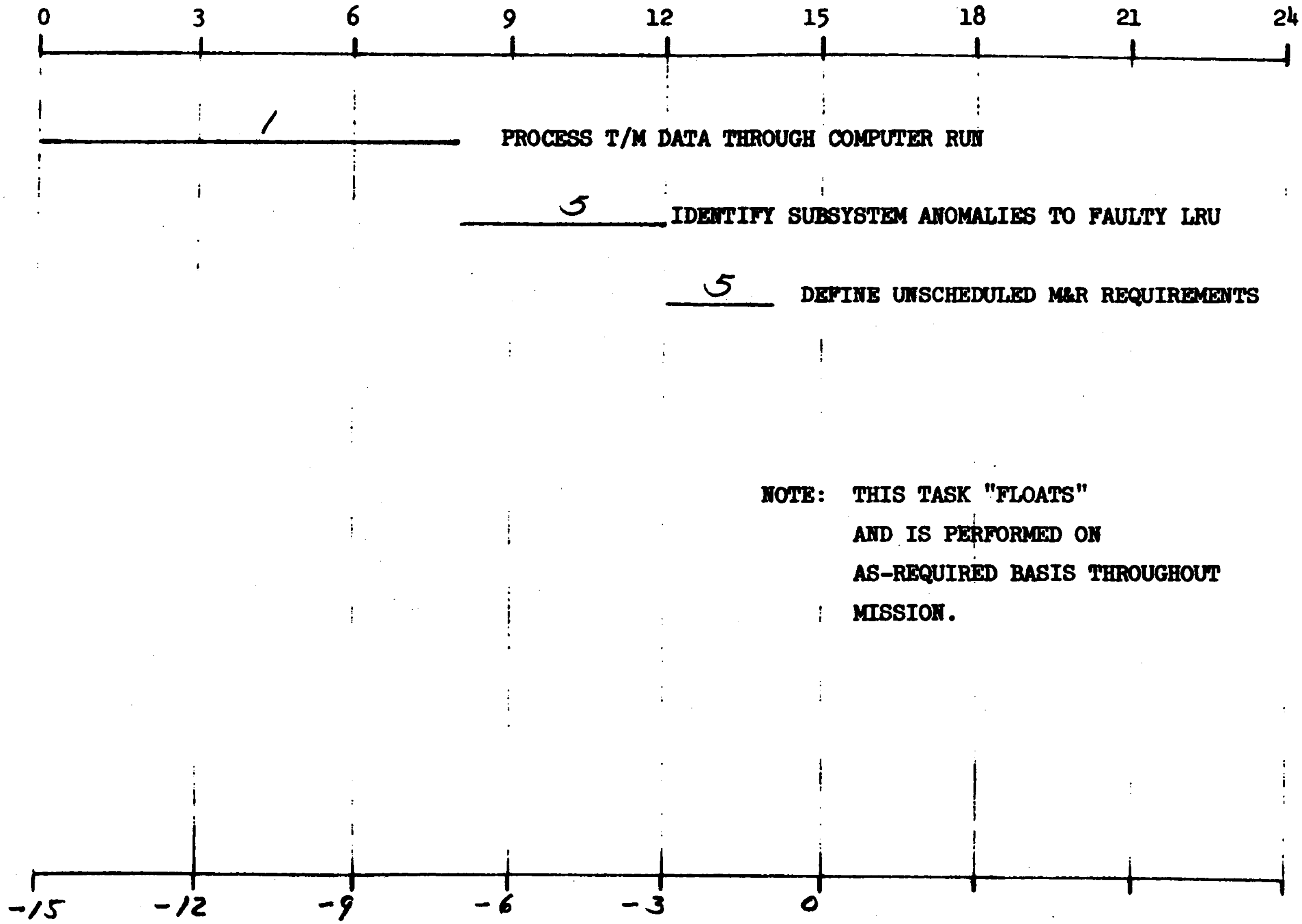
SEPTEMBER 1973

11-168

OPTION NUMBER 3I KSC	FUNCTION TITLE PREPARE PRELIMINARY M&R SCHEDULE	FLOW BLOCK NO. 1.1.1



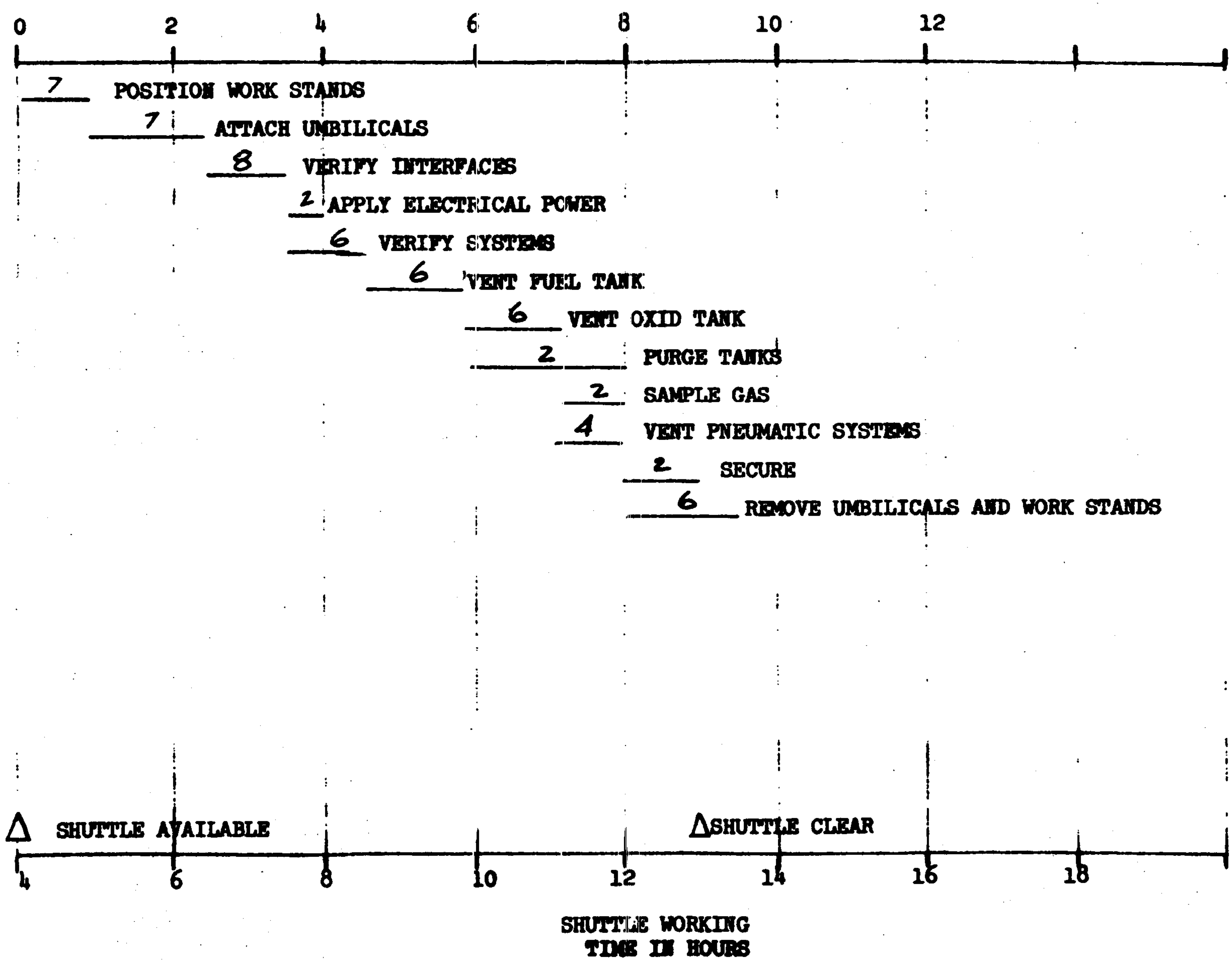
OPTION NUMBER	3I KSC	FUNCTION TITLE	ANALYZE T/M FOR UNSCHEDULE M&R	FLOW BLOCK NO.	1.1.2



NOTE: THIS TASK "FLOATS" AND IS PERFORMED ON AS-REQUIRED BASIS THROUGHOUT MISSION.

TIME IN HOURS

OPTION NUMBER 3I KSC	FUNCTION TITLE TUG GROUND SAFING AT SAFING AREA	FLOW BLOCK NO. 3.1.1

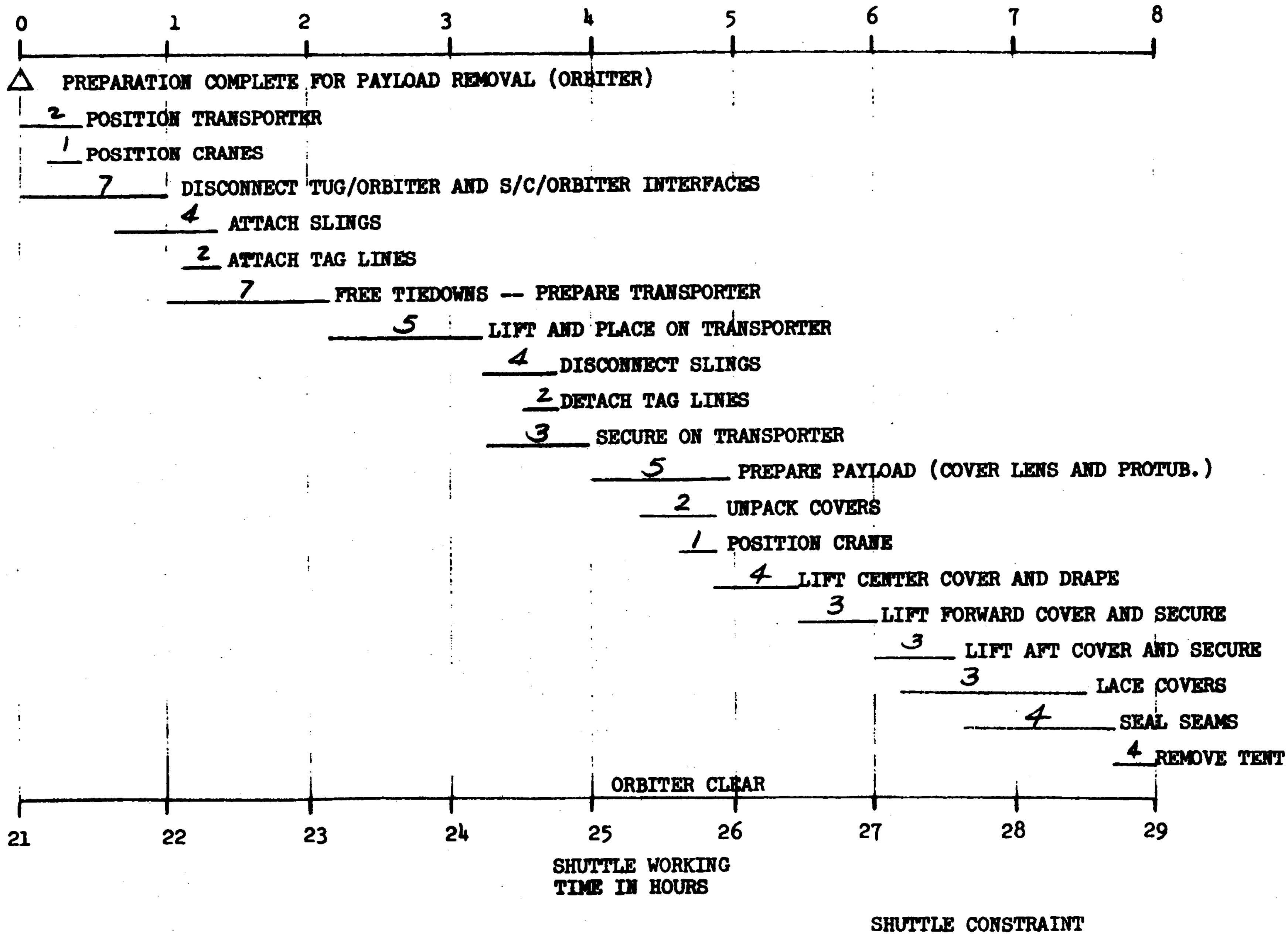


NOTE: NO RESIDUAL LIQUIDS

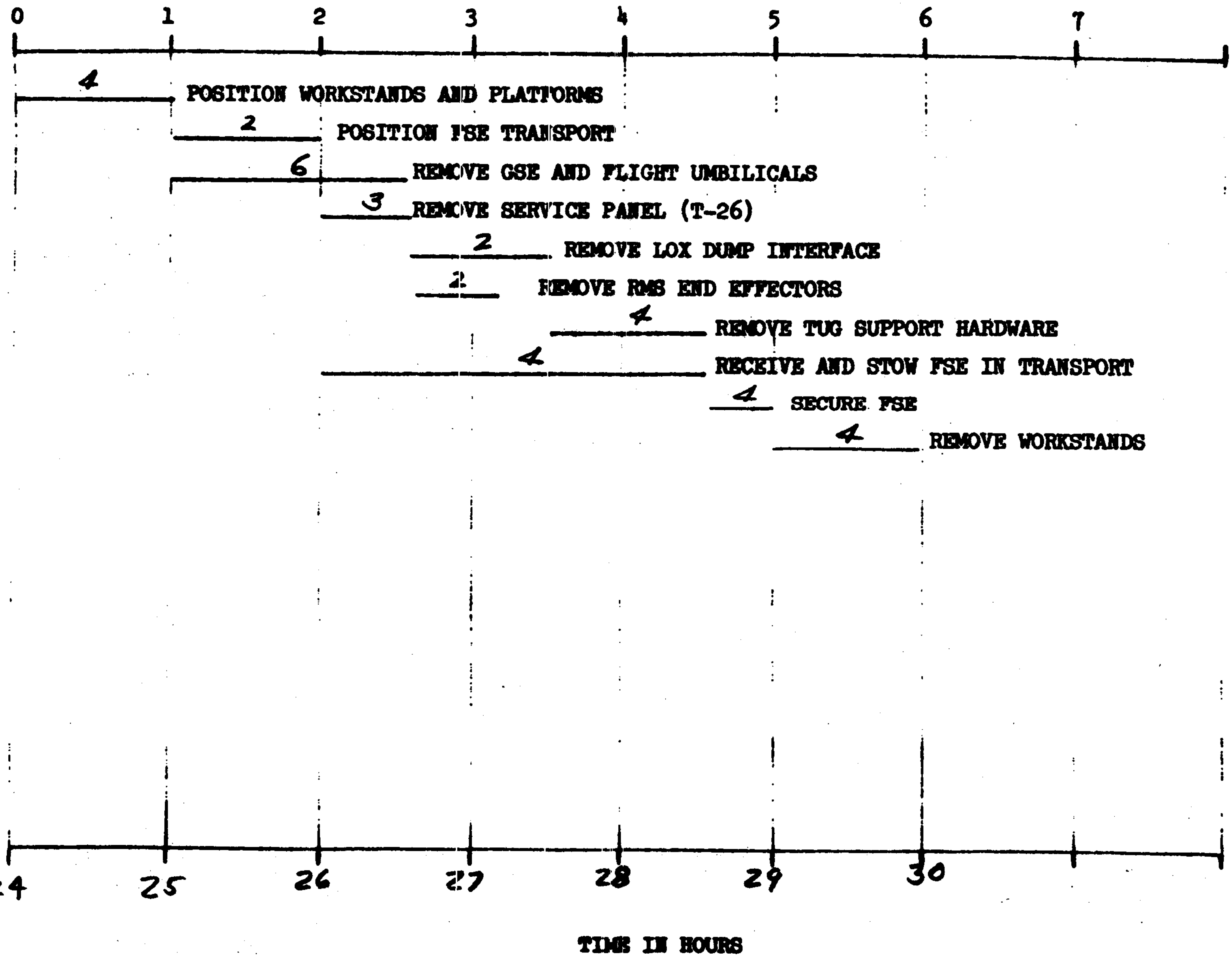
SHUTTLE CONSTRAINTS

11-1-71

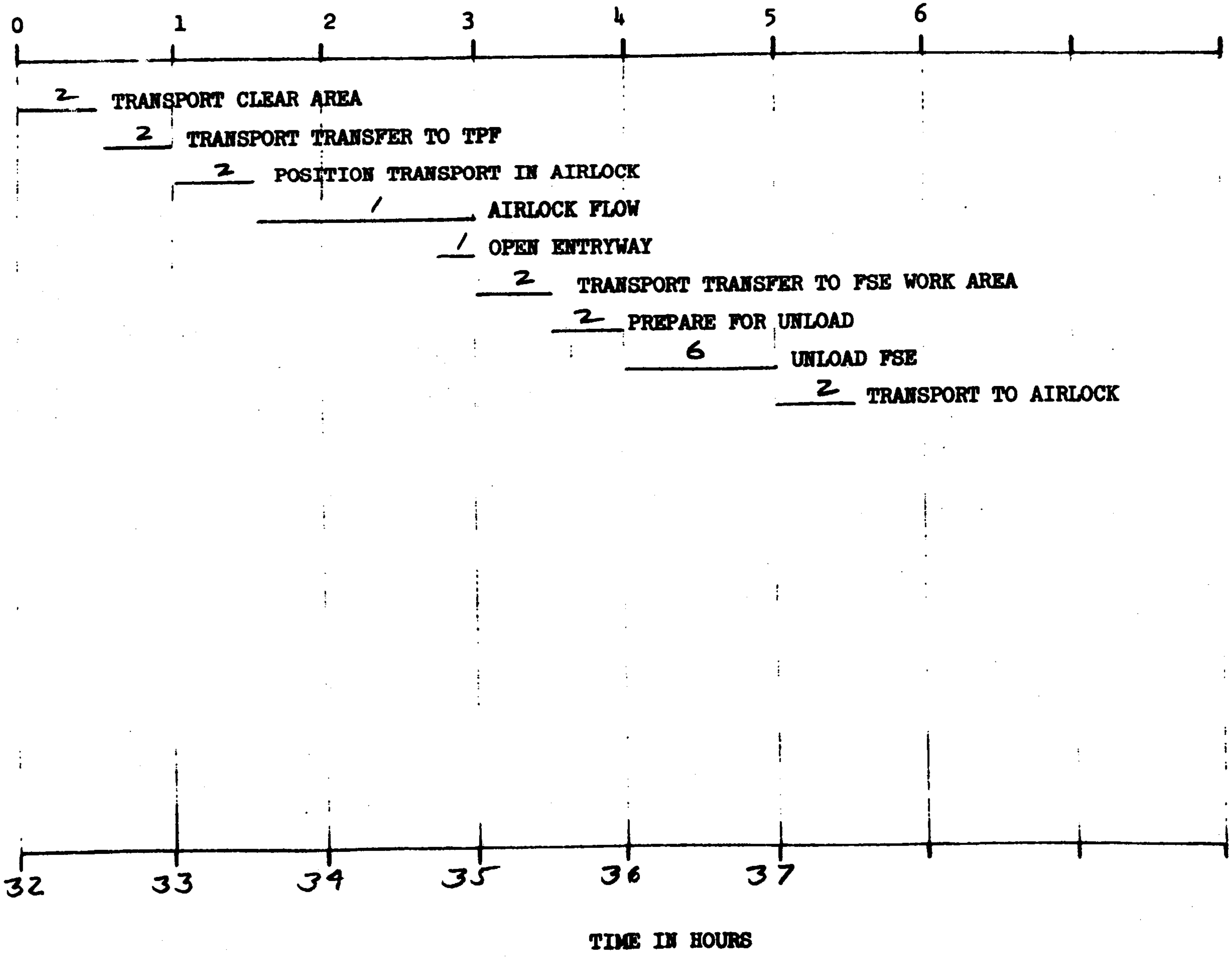
OPTION NUMBER 3I KSC	FUNCTION TITLE RECOVER TUG AND S/C AT MCF	FLOW BLOCK NO. 3.2.5



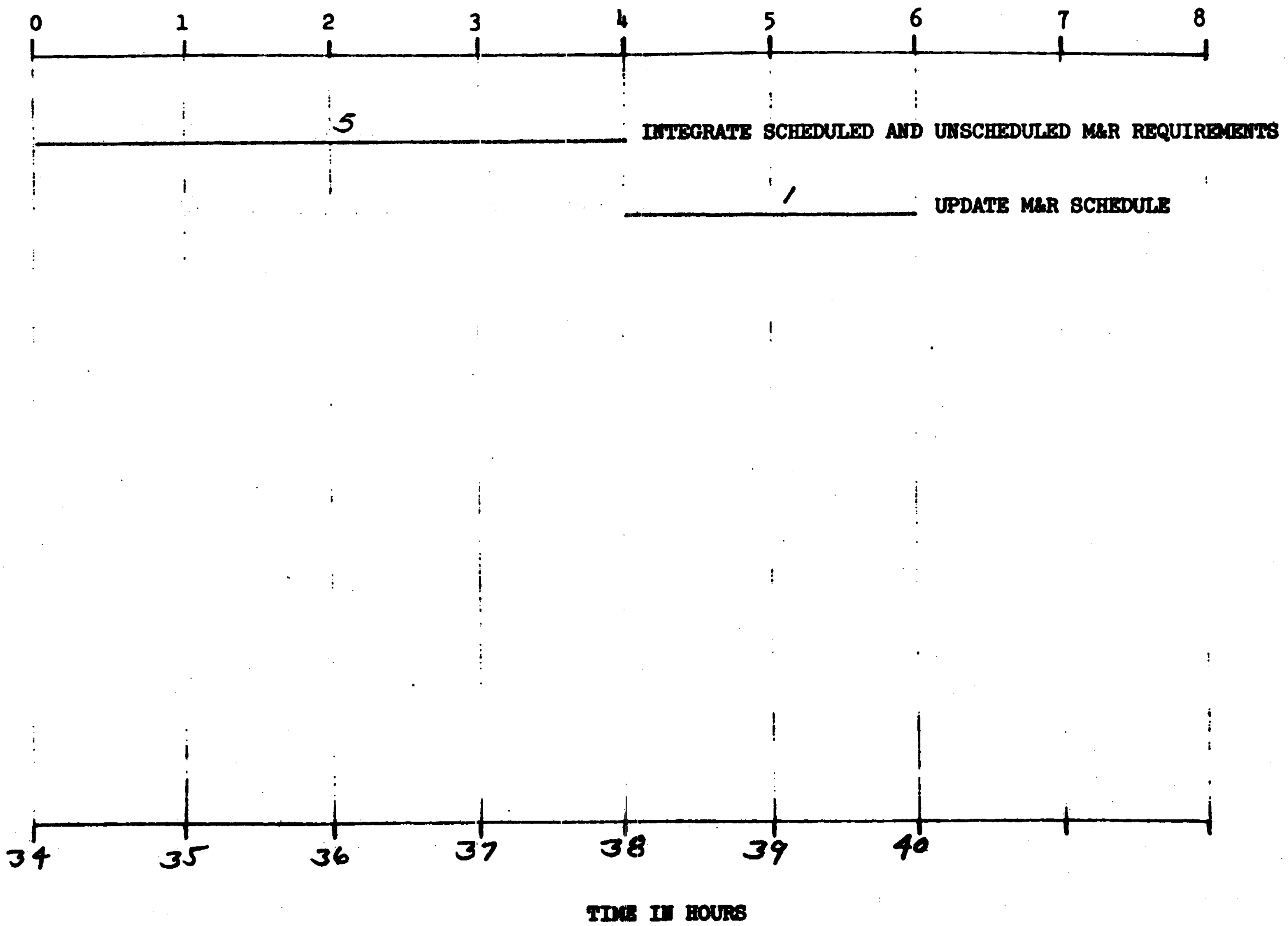
OPTION NUMBER	3I KSC ALL	FUNCTION TITLE	RECOVER FSE (PAYLOAD BAY) EQUIPMENT	FLOW BLOCK NO.	3.2.7



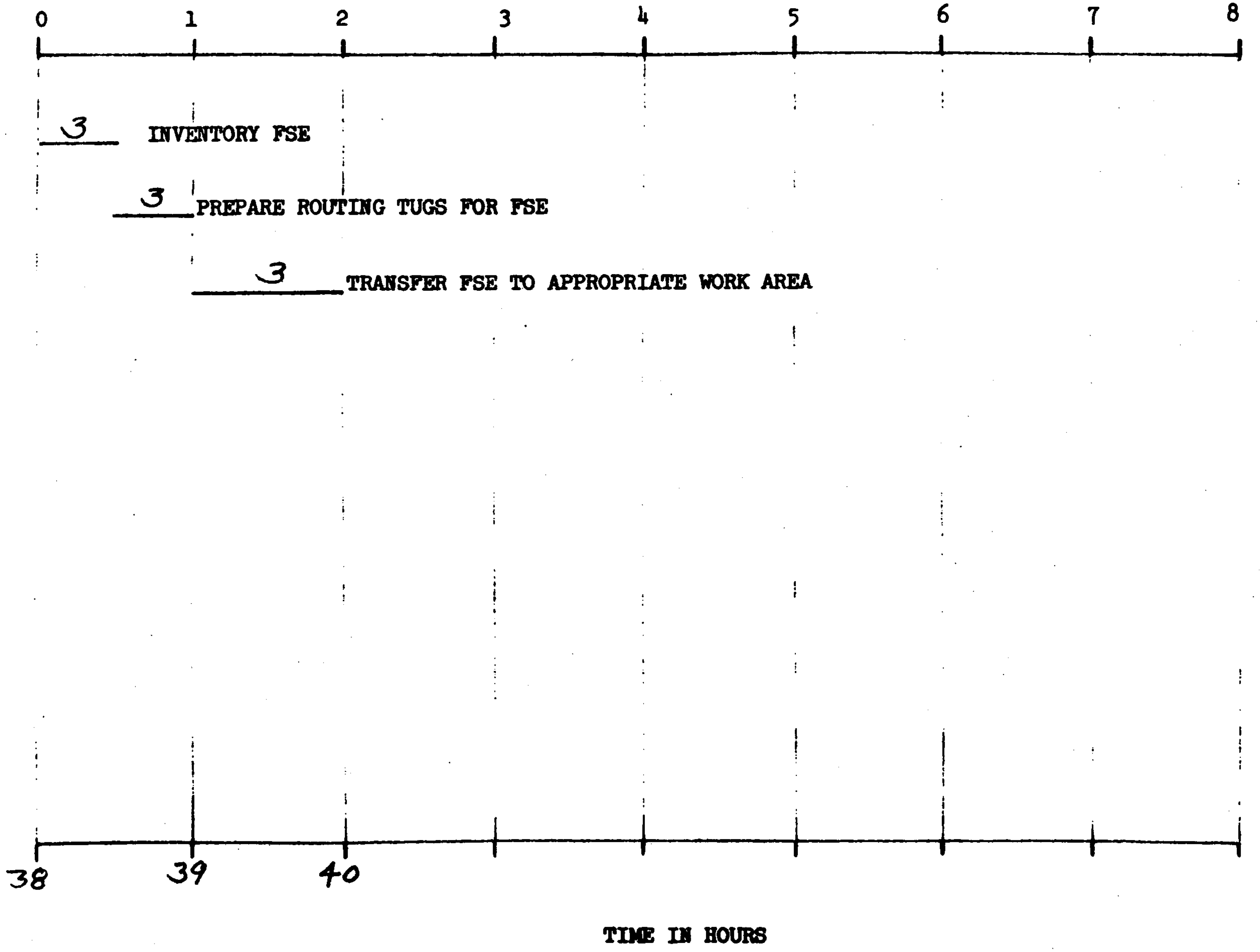
OPTION NUMBER 3I KSC	FUNCTION TITLE TRANSFER FSE TO TPF	FLOW BLOCK NO. 3.2.9



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I KSC	UPDATE M&R SCHEDULE	1.1.3



OPTION NUMBER 3I KSC	FUNCTION TITLE RECEIVE FSE AT TPF/PPF	FLOW BLOCK NO. 1.1.15



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I KSC	TRANSFER TUG AND S/C TO SPF	3.1.4

0 1 2 3 4 5 6 7

2 SECURITY ESCORT*

2 MAKE POSITIVE PRESSURE PURGE I/F WITH COVER

2 INITIATE PURGE

2 ATTACH TRACTOR AND CLEAR AREA

2 TRANSFER TO SPF

2 POSITION TRANSPORTER

4 POSITION PORTABLE TENT

2 INITIATE CEILING TO FLOOR FLOW/TERMINATE PURGE

3 REMOVE AFT COVER

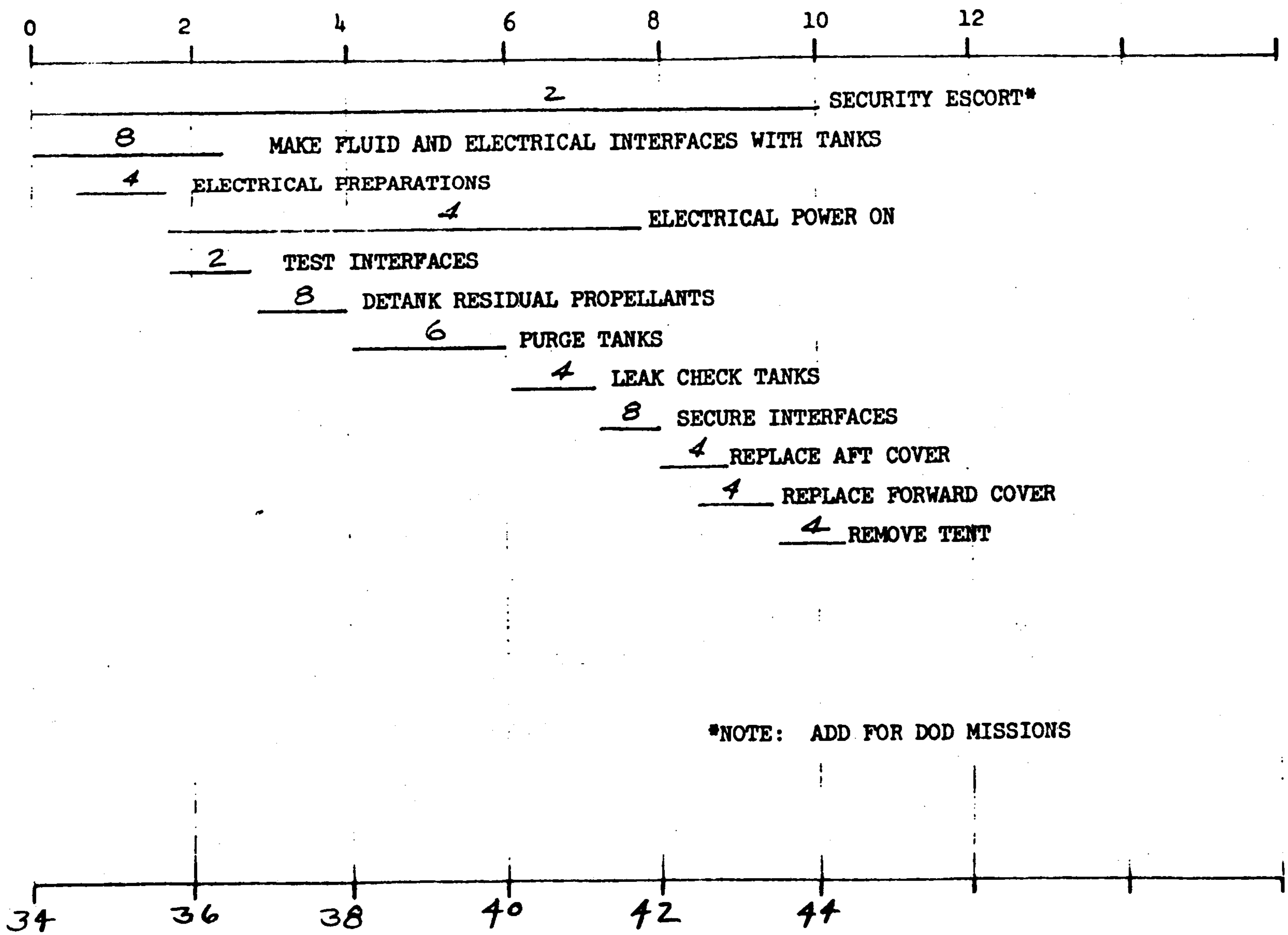
3 REMOVE FORWARD COVER

*NOTE: ADD FOR DOD MISSIONS

29 30 31 32 33 34

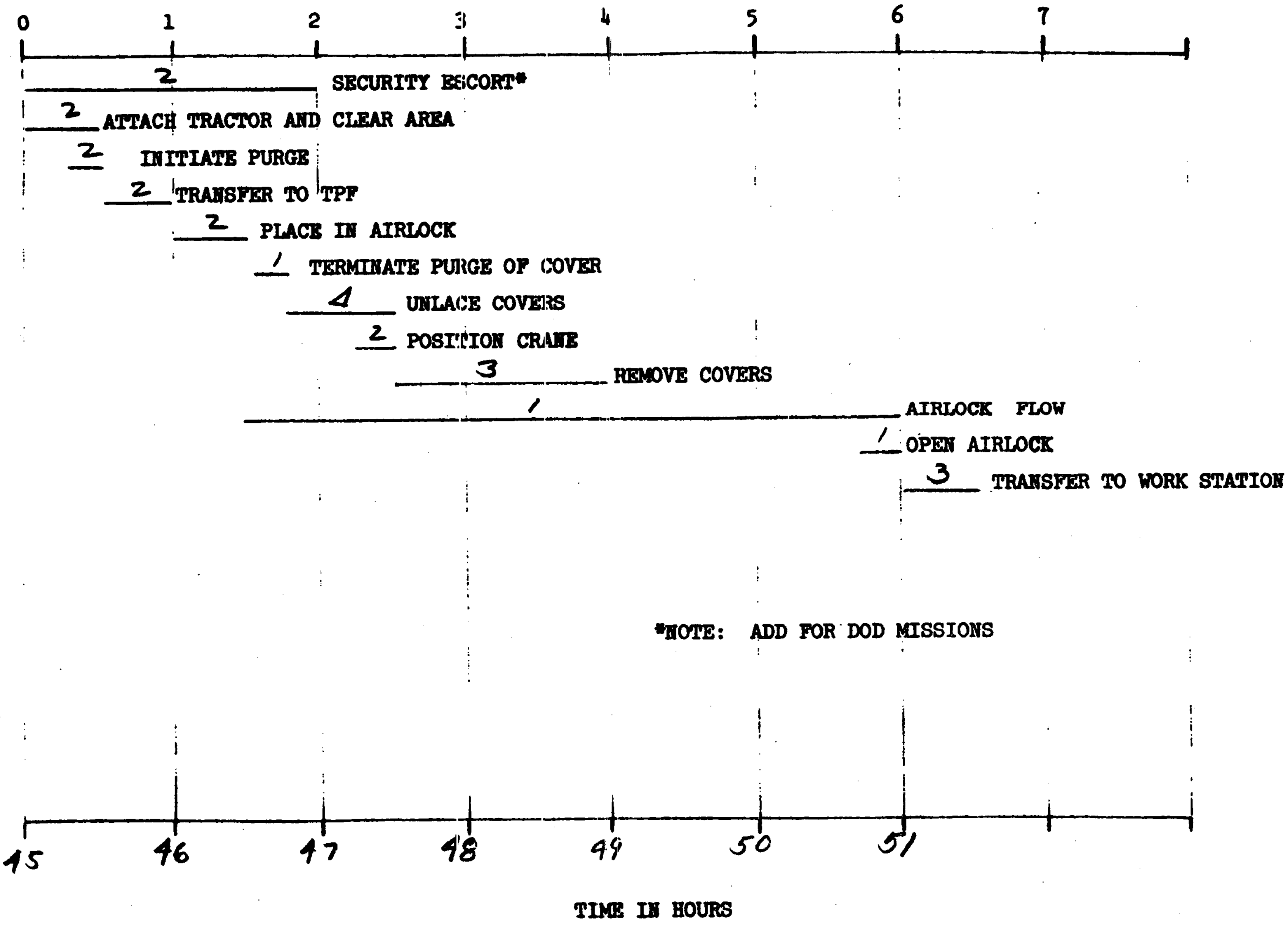
TIME IN HOURS

OPTION NUMBER	FUNCTION TITLE TUG SAFING	FLOW BLOCK NO. 3.1.6

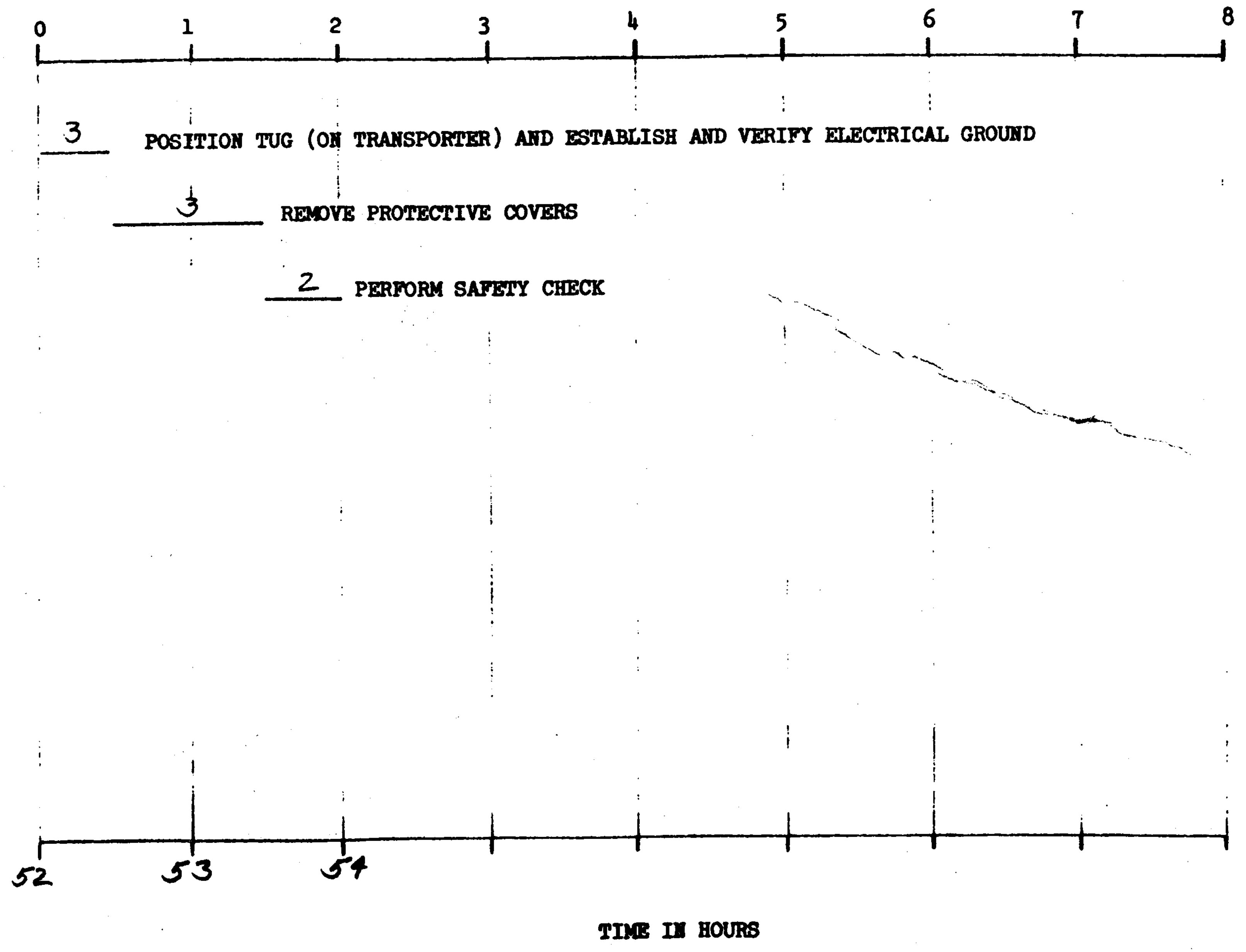


NOTES: MONOPROPELLANT AT SPF

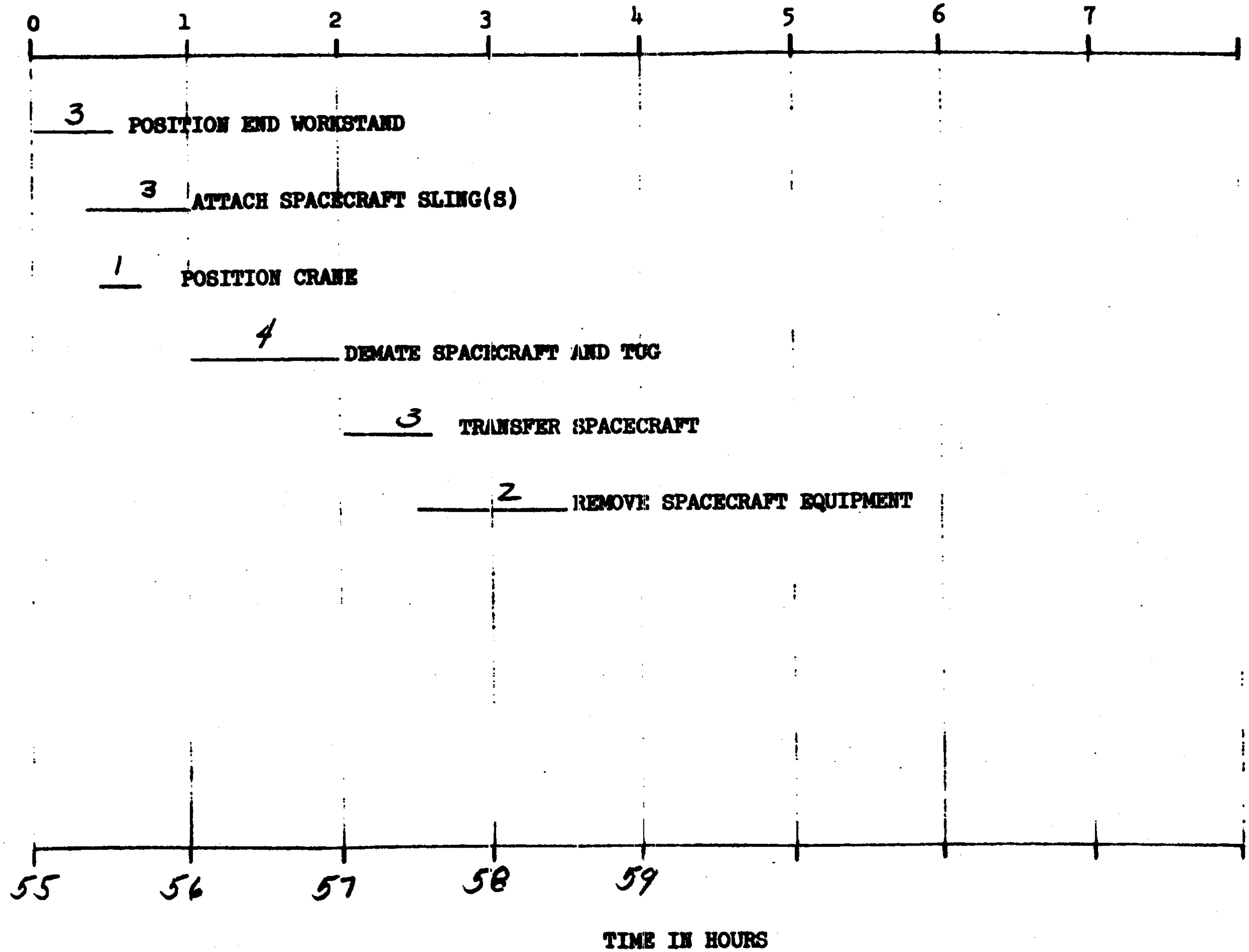
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I KSC	TRANSFER TUG AND SPACECRAFT TO TPF	3.3.6



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I KSC	RECEIVE TUG AT TPF/PPF	1.1.4



OPTION NUMBER	3I KSC	FUNCTION TITLE	DEMATE TUG AND SPACECRAFT	FLOW BLOCK NO.	3.3.2



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I KSC	PREPARE FOR INSPECTION AND C/O	1.1.5

0 1 2 3 4 5 6 7 8

6 POSITION WORKSTANDS

6 OPEN ACCESS PANELS/DOORS

3 INSTALL AIR CONDITIONING (BREATHABLE AIR) IN CONFINED AREAS

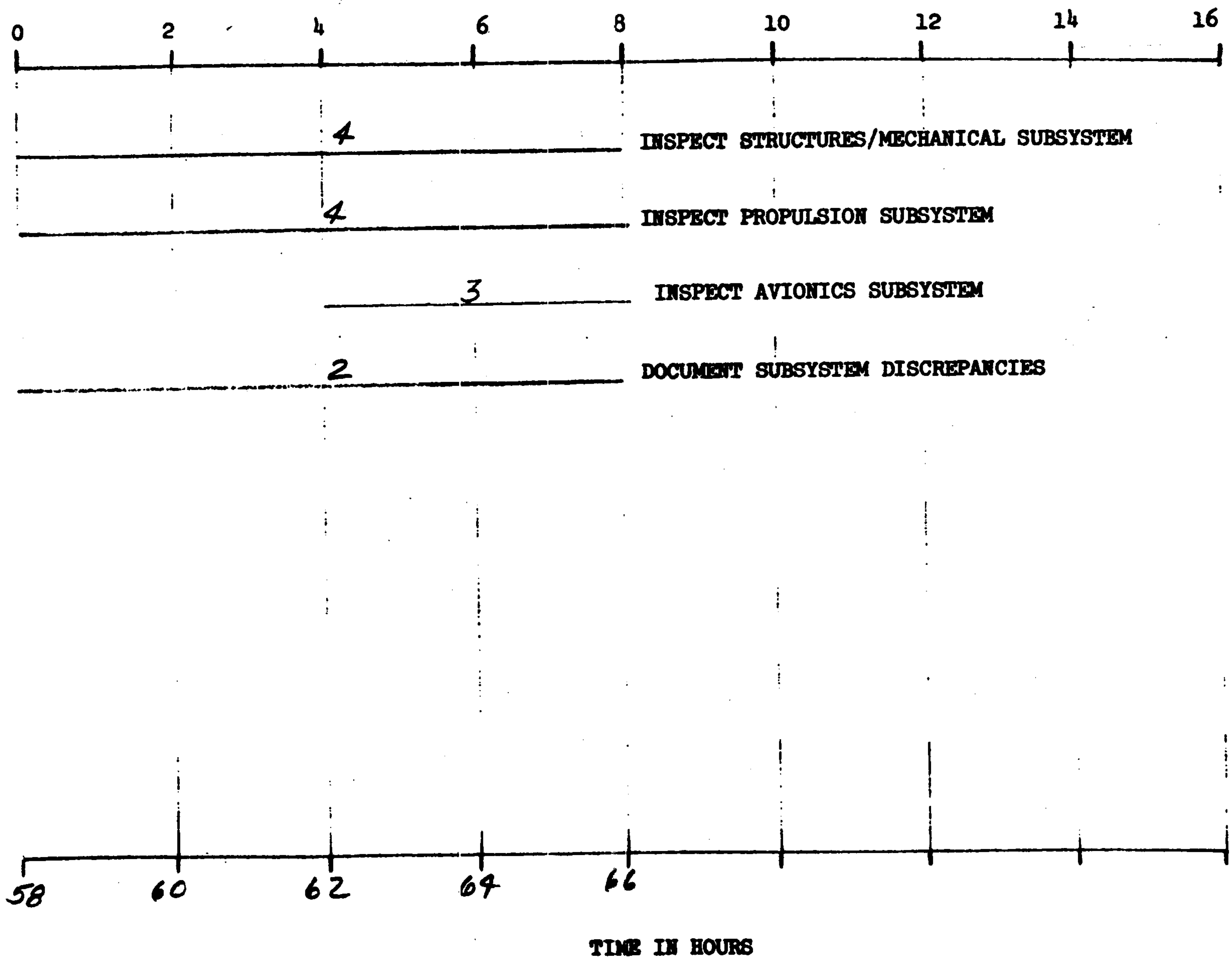
4 REMOVE FORWARD SKIRT METEOROID BARRIER

4 POSITION/CONNECT REQUIRED GSE AND GROUND POWER AND PERFORM SELF CHECK

54 55 56 57 58

TIME IN HOURS

OPTION NUMBER 3I KSC	FUNCTION TITLE PERFORM POST FLIGHT RECEIVING INSPECTION	FLOW BLOCK NO. 1.1.6



OPTION NUMBER 3I KSC	FUNCTION TITLE PREPARE FOR INSPECTION	FLOW BLOCK NO. 1.1.16

0 1 2 3 4 5 6 7 8

4 REMOVE TILT TABLE FROM TUG AND REMOVE COMPONENTS FROM TILT TABLE (AS REQUIRED)

4 CLEAN FSE EXTERNAL SURFACES

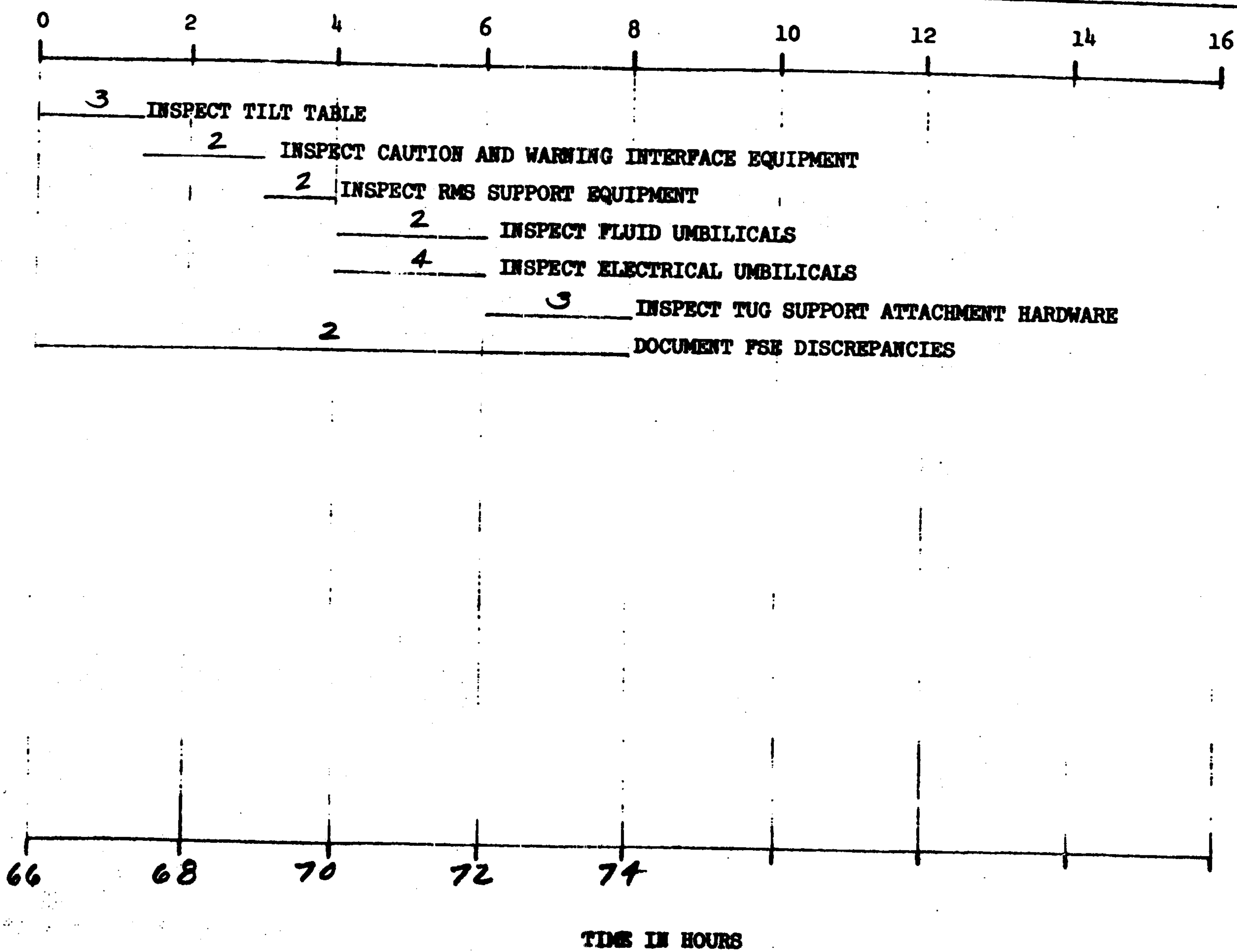
4 POSITION/CONNECT REQUIRED GSE AND GROUND POWER AND PERFORM SELF CHECK

58 59 60 61 62

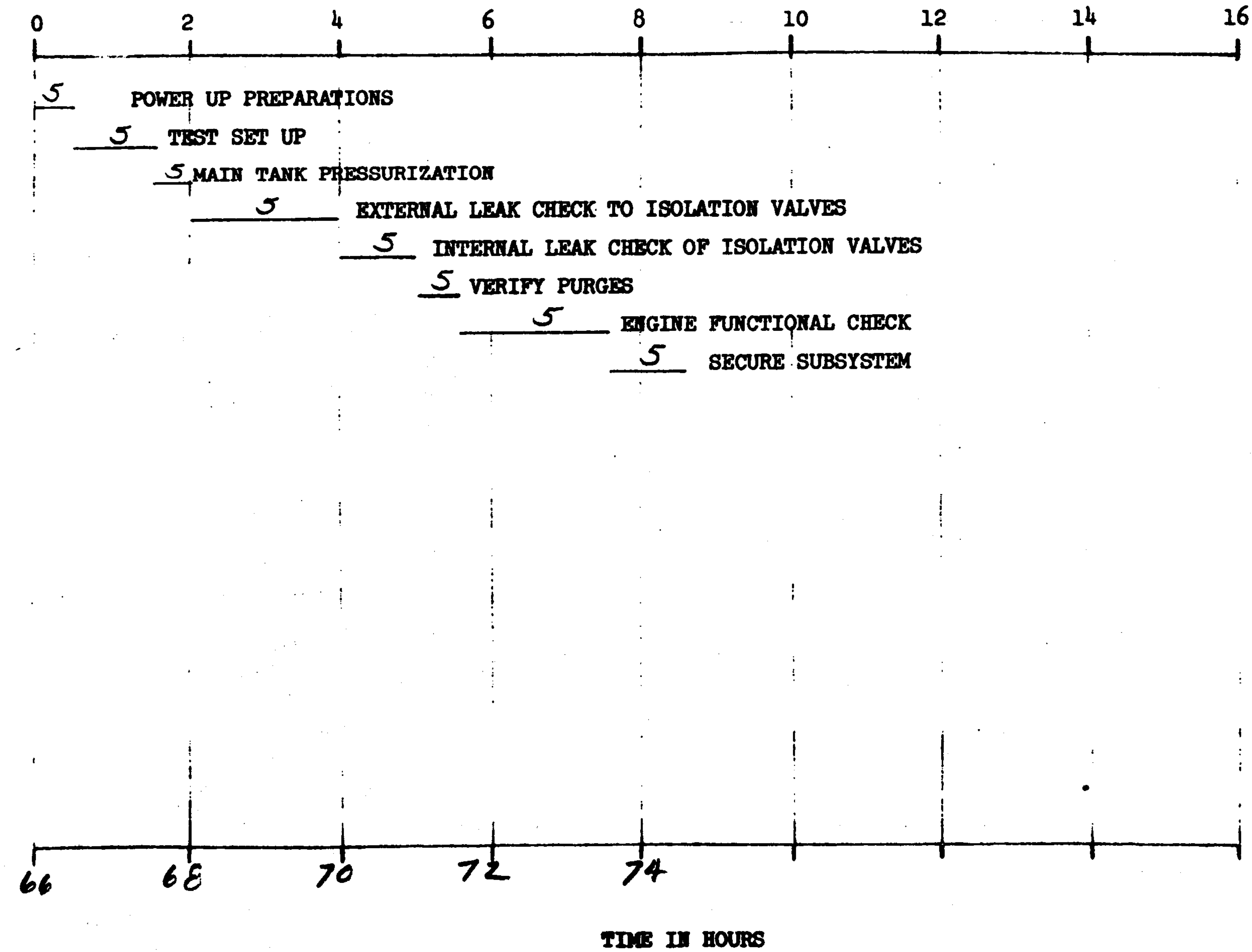
TIME IN HOURS

11-184

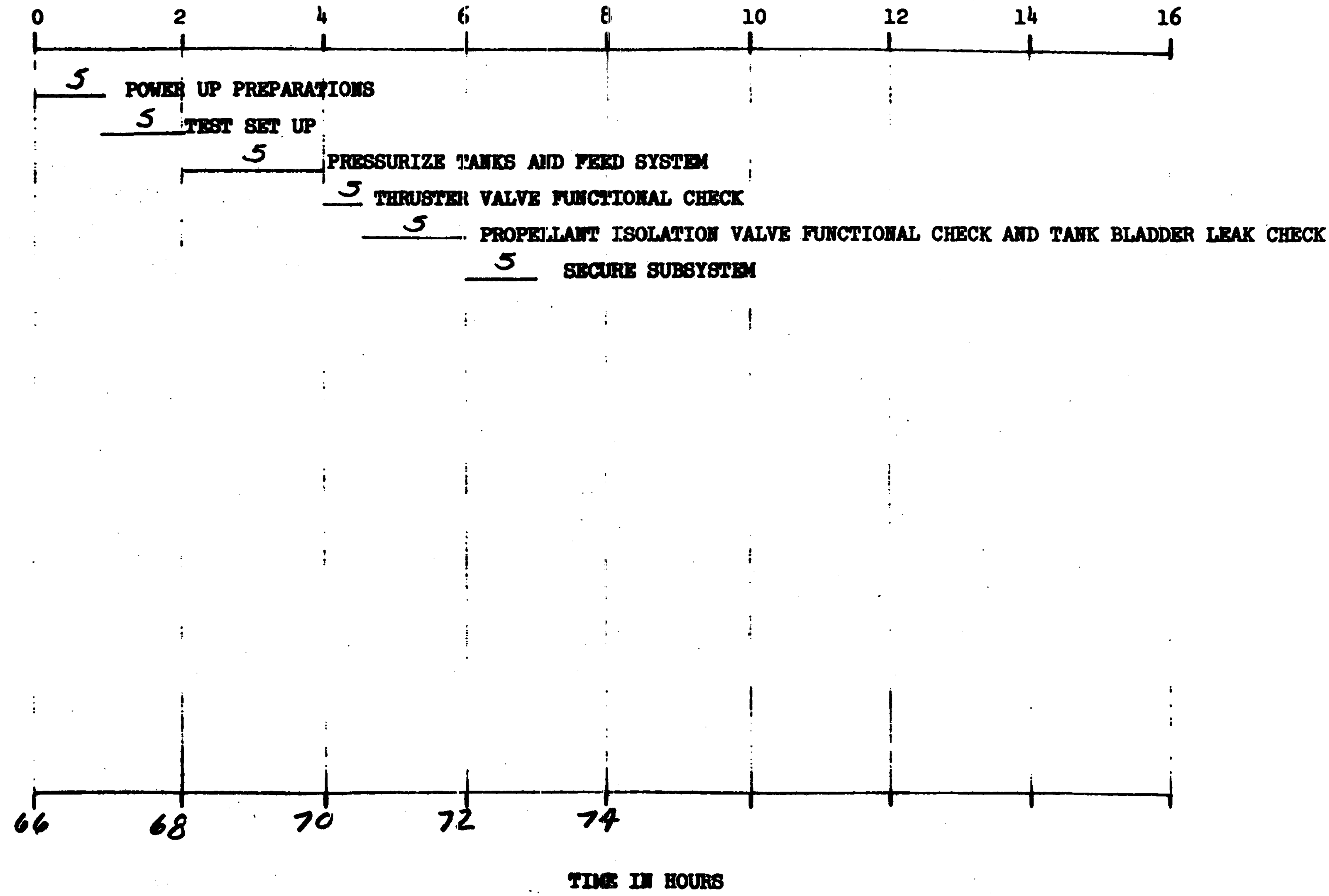
OPTION NUMBER 3I KSC	FUNCTION TITLE PERFORM FSE POST FLIGHT/RECEIVING INSPECTION	FLOW BLOCK NO.	1.1.17



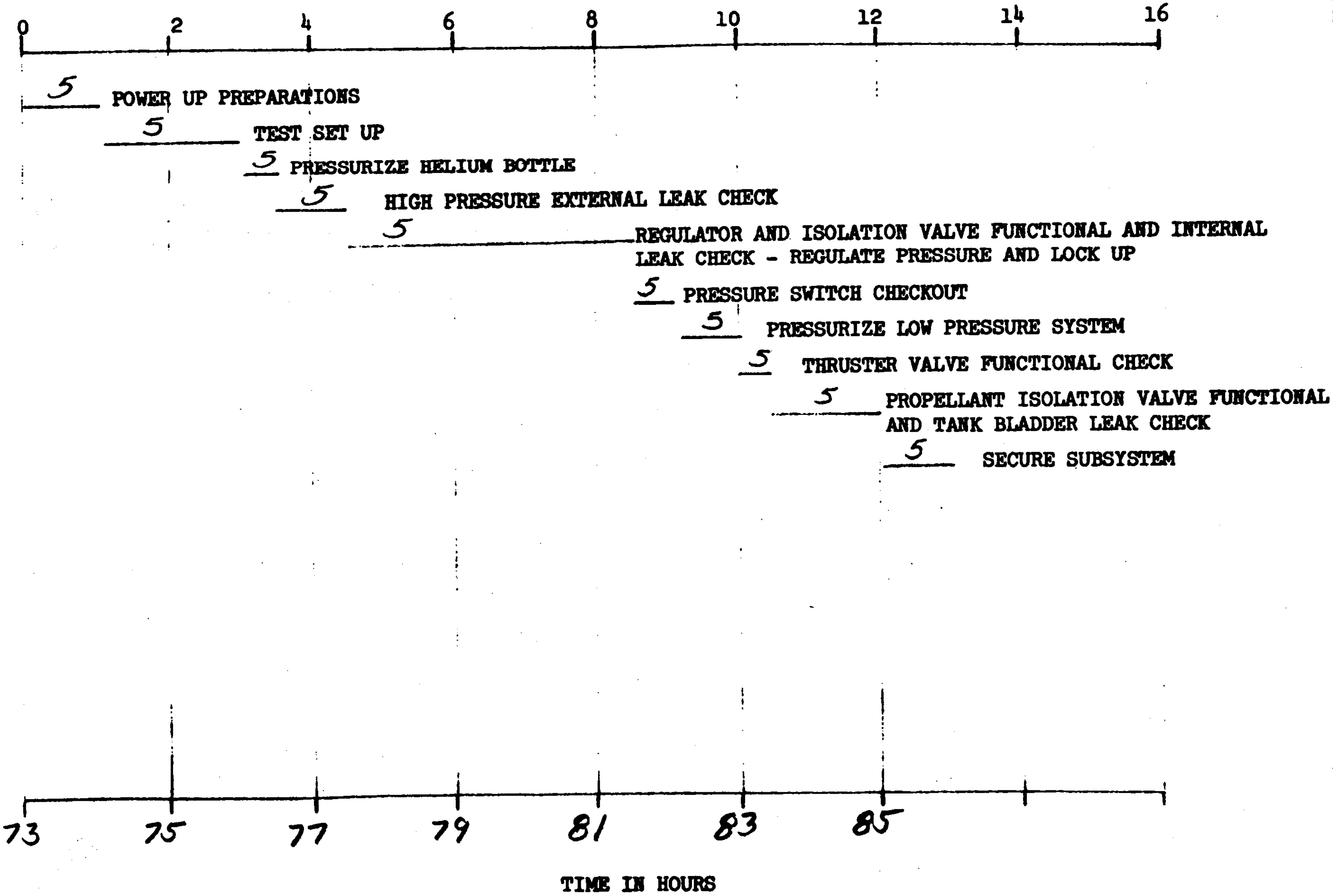
OPTION NUMBER 3T KSC	FUNCTION POST FLIGHT CHECKOUT - MAIN PROPULSION TITLE PRESSURIZATION - AMBIENT HELIUM & GH_2 BLEED	FLOW BLOCK NO. 1.1.7.1



OPTION NUMBER 3I KSC	FUNCTION TITLE POST FLIGHT CHECKOUT - APS SUBSYSTEM - MONOPROPELLANT - BLOWDOWN	FLOW BLOCK NO. 1.1.7.5



OPTION NUMBER	3I KSC	FUNCTION TITLE	POST FLIGHT CHECKOUT - APS SUBSYSTEM MONOPROPELLANT - PRESSURIZED	FLOW BLOCK NO.	1.1.7.6



OPTION NUMBER 3I-KSC	FUNCTION TITLE POST FLIGHT CHECKOUT - AVIONICS	FLOW BLOCK NO. 1.1.7.9

0 8 16 24 32 40

5 VERIFY GSE, INTERFACES AND CONNECT CABLES

1 POWER TURN ON

3 CALIBRATION

3 ALL SYSTEMS TEST

1 POWER OFF

3 DISCONNECT GSE

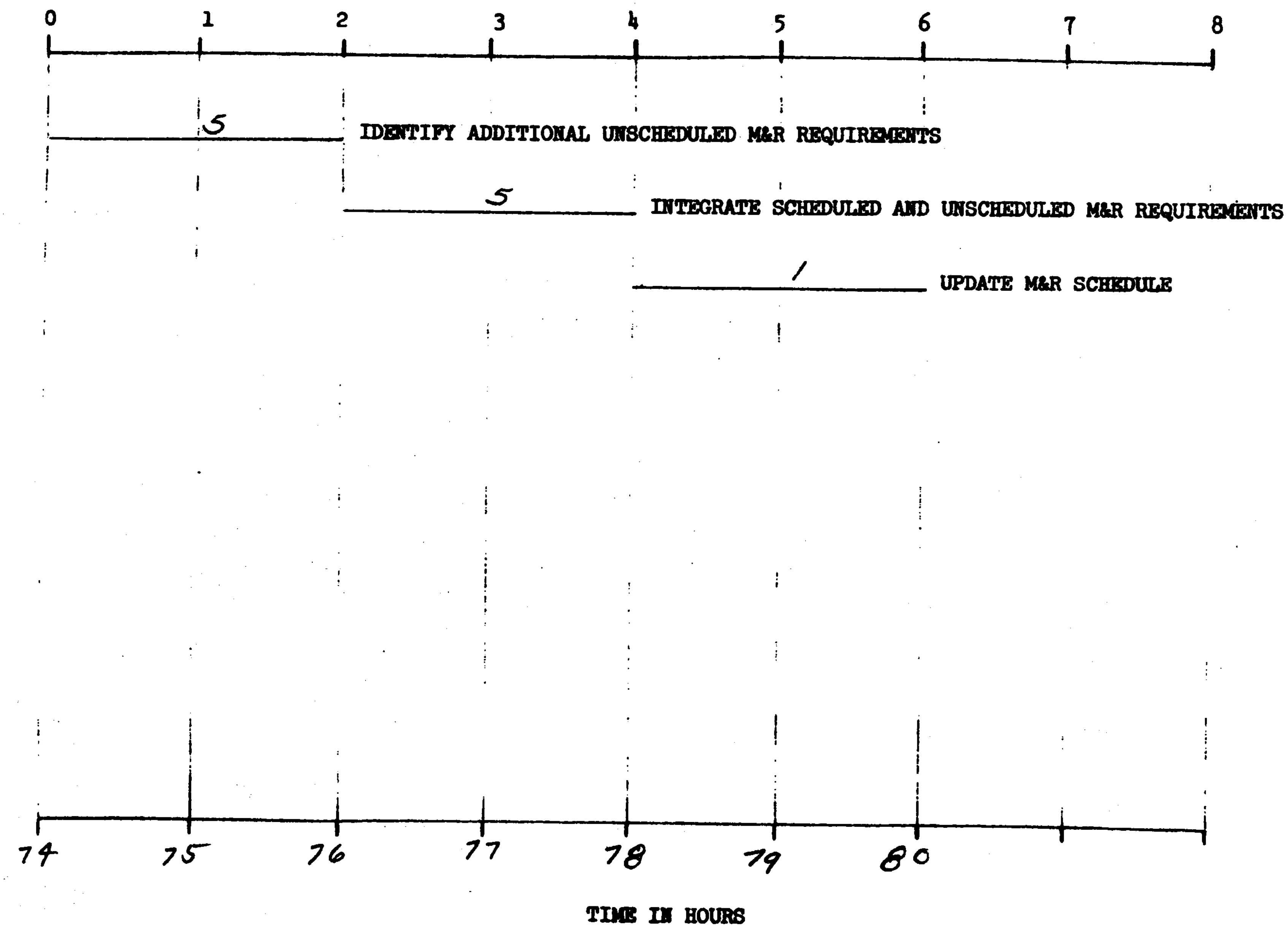
NOTE: 1. APPROXIMATELY 1/3 OF INSTRUMENTATION CALIBRATED AFTER EACH MISSION.

2. PROPULSION AND AVIONICS POST FLIGHT CHECKOUTS TO BE RUN CONCURRENTLY.

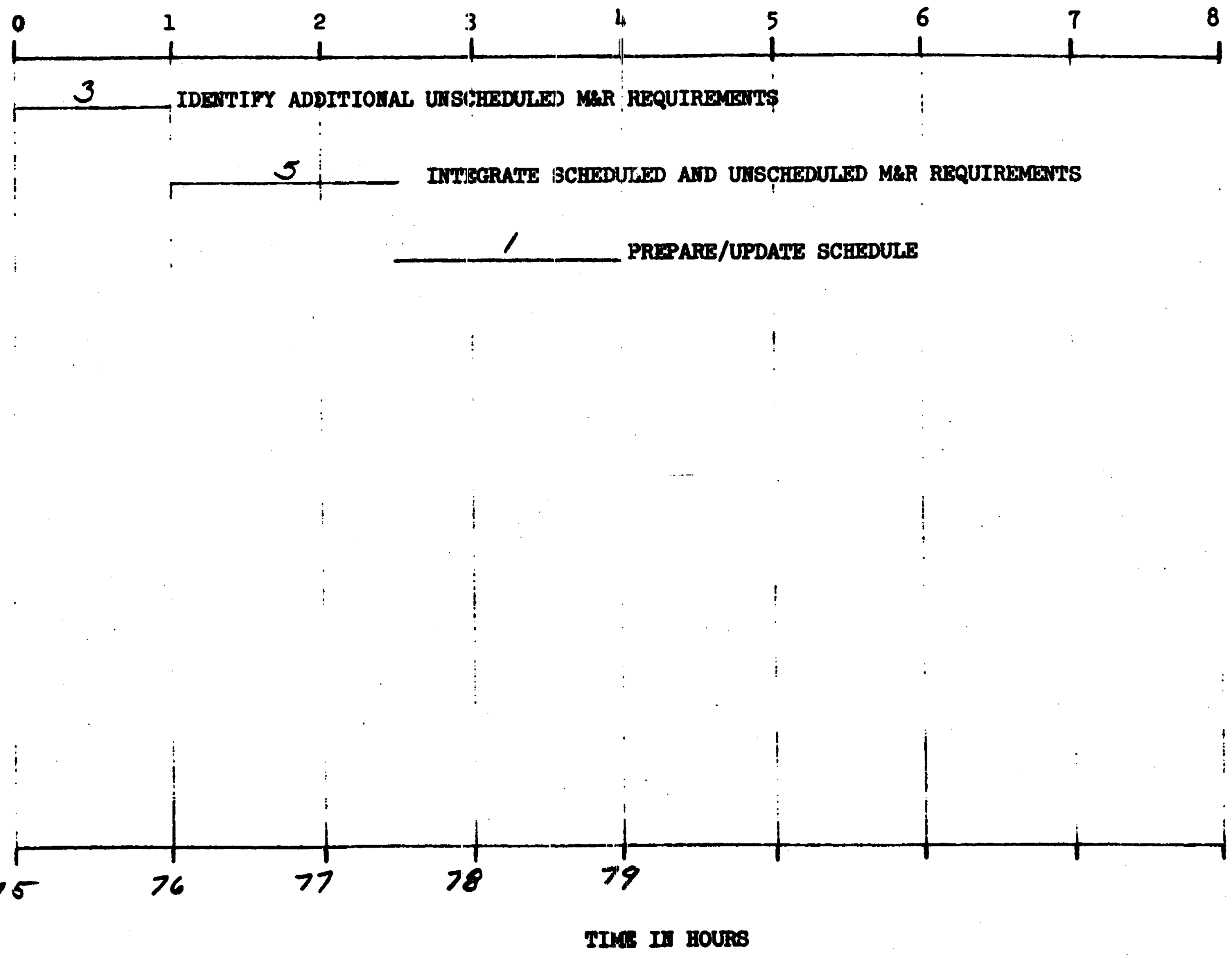
66 74/90 98 106 114 122

TIME IN HOURS

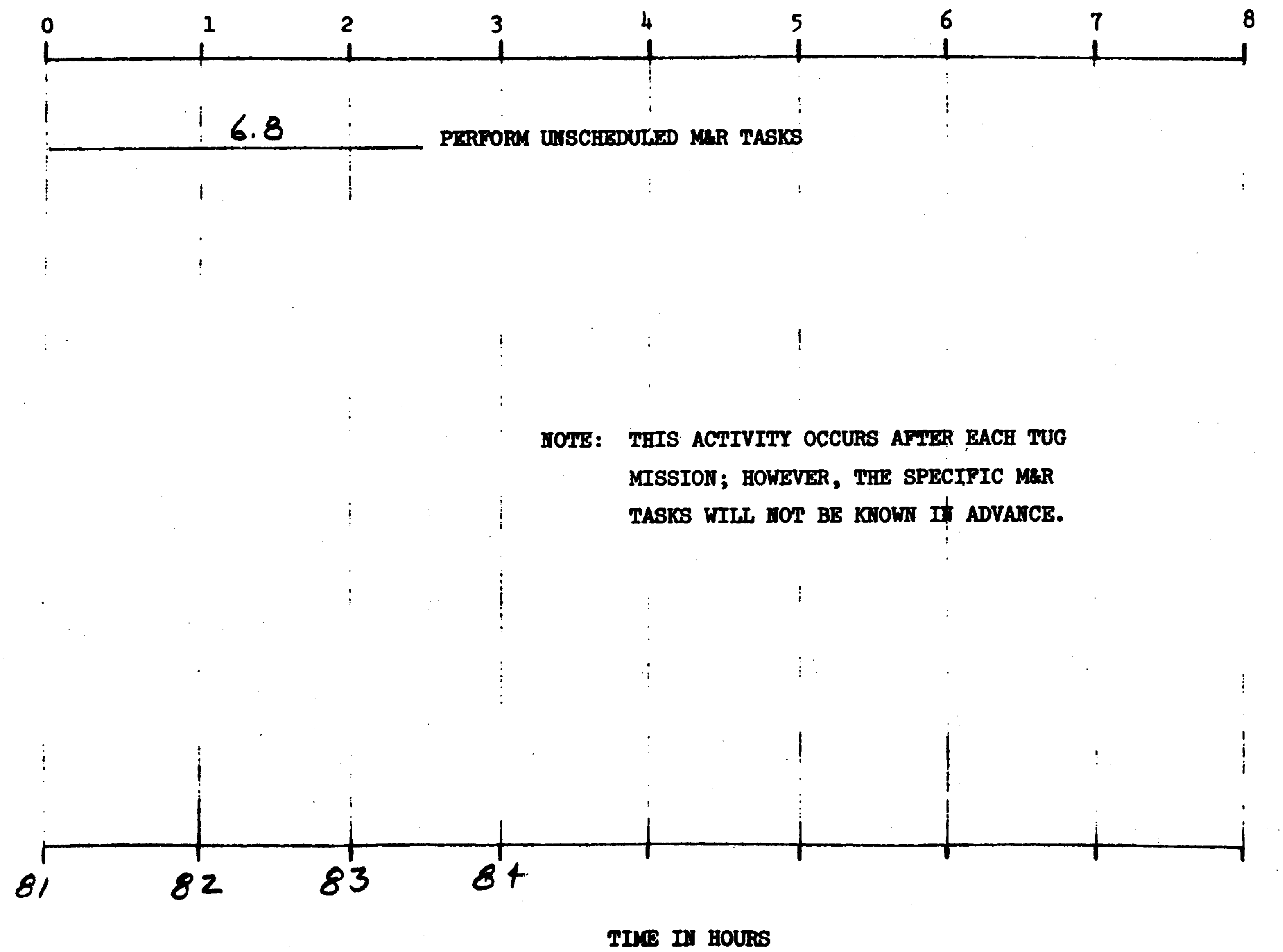
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I KSC	PREPARE/UPDATE M&R SCHEDULE	1.1.10



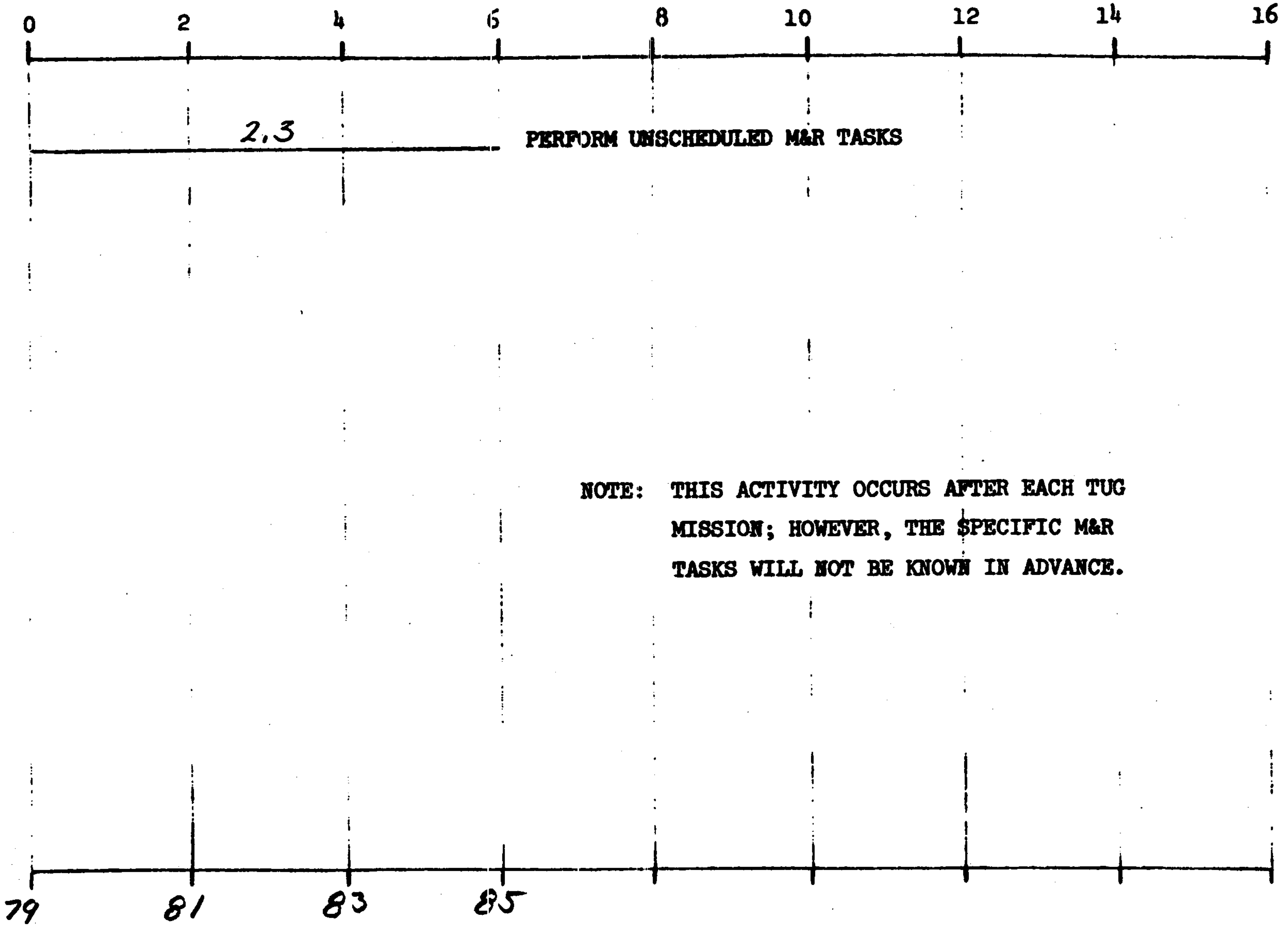
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I KSC	PREPARE/UPDATE M&R SCHEDULE	1.1.18



OPTION NUMBER 3I KSC	FUNCTION TITLE PERFORM STRUCTURAL/MECHANICAL M&R	FLOW BLOCK NO. 1.1.11



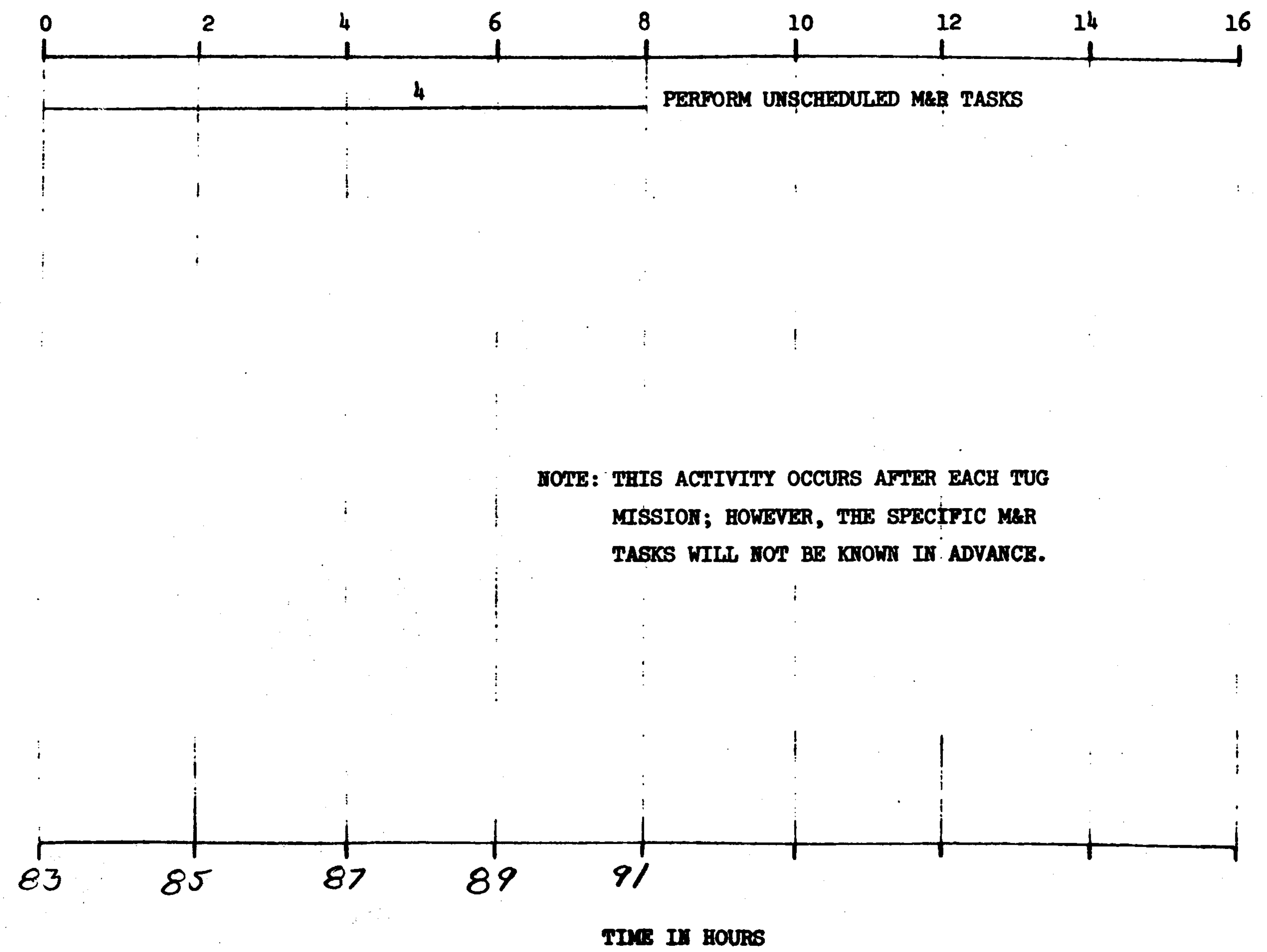
OPTION NUMBER 3I KSC	FUNCTION TITLE	PERFORM PROPULSION M&R	FLOW BLOCK NO.	1.1.12



NOTE: THIS ACTIVITY OCCURS AFTER EACH TUG MISSION; HOWEVER, THE SPECIFIC M&R TASKS WILL NOT BE KNOWN IN ADVANCE.

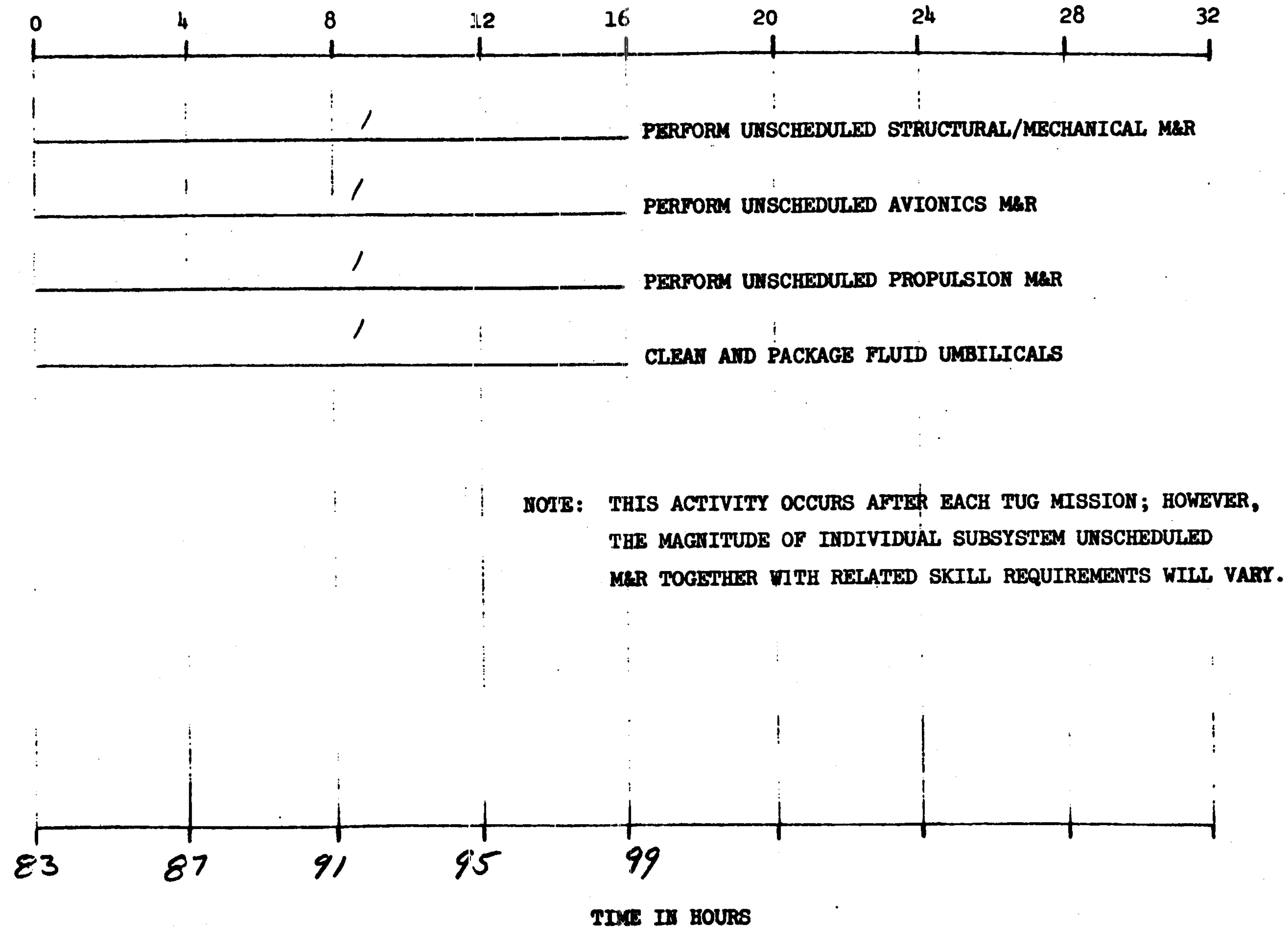
TIME IN HOURS

OPTION NUMBER 3I KSC	FUNCTION TITLE PERFORM AVIONICS M&R	FLOW BLOCK NO. 1.1.13



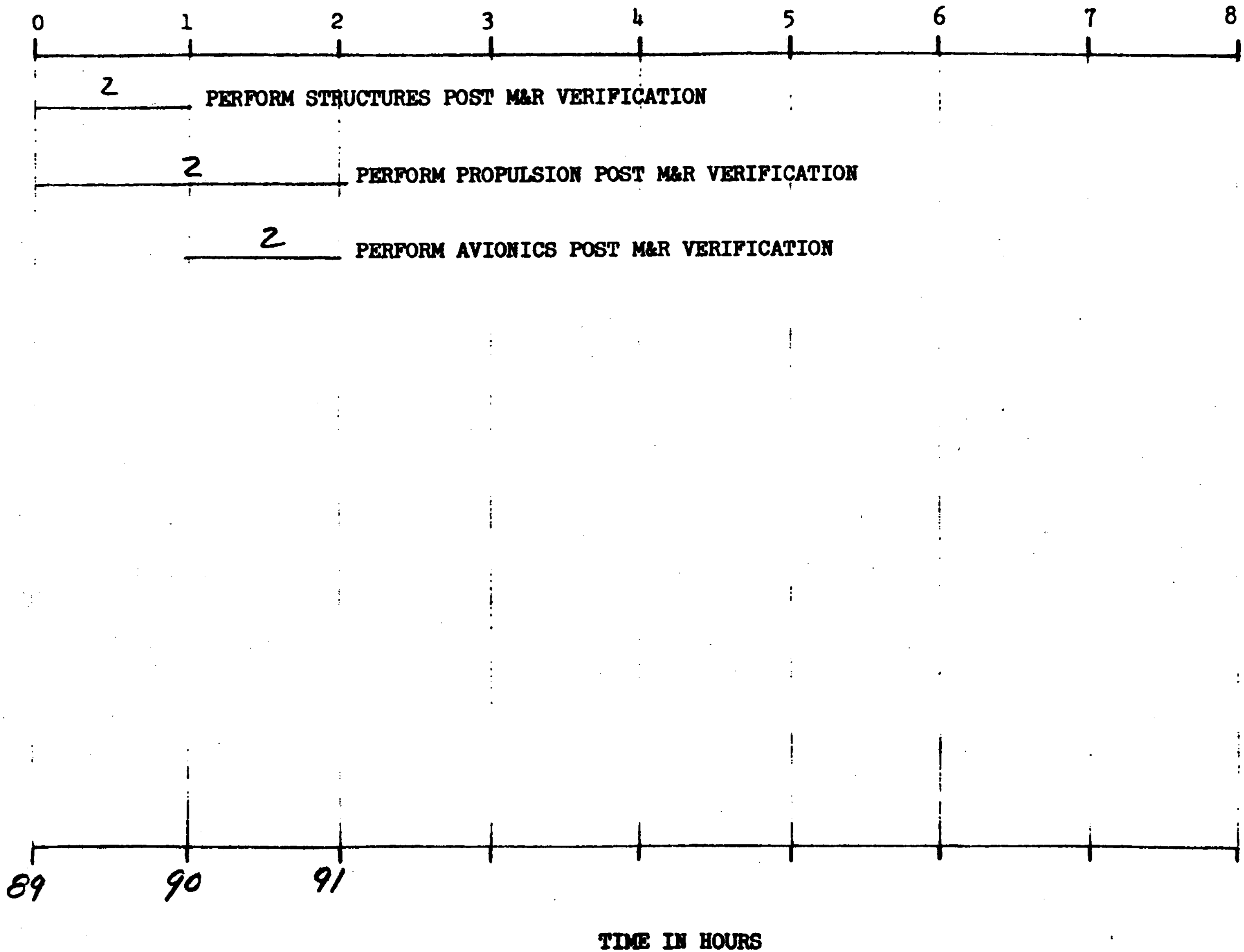
NOTE: THIS ACTIVITY OCCURS AFTER EACH TUG MISSION; HOWEVER, THE SPECIFIC M&R TASKS WILL NOT BE KNOWN IN ADVANCE.

OPTION NUMBER 3I KSC	FUNCTION TITLE PERFORM FSE M&R	FLOW BLOCK NO. 1.1.19

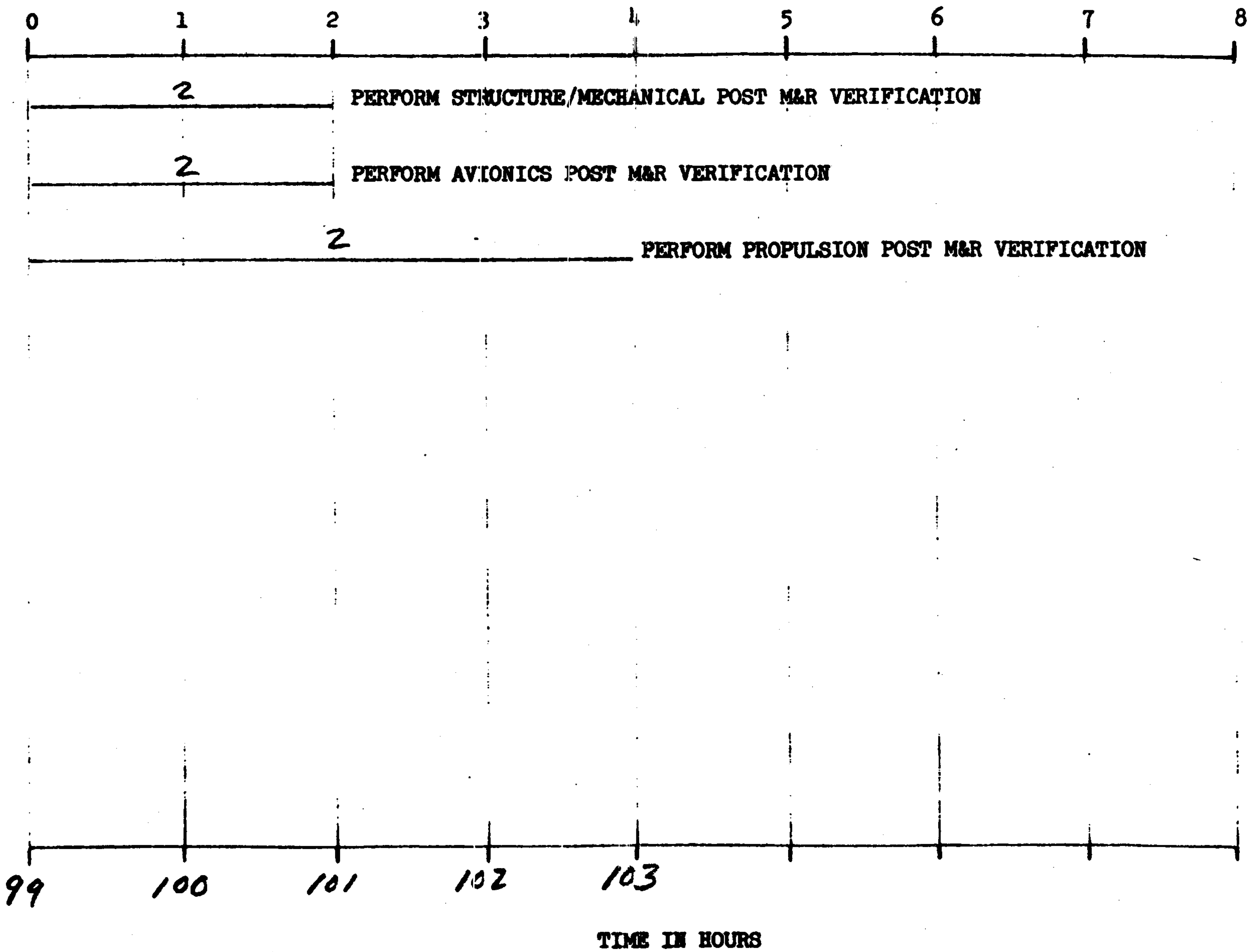


NOTE: THIS ACTIVITY OCCURS AFTER EACH TUG MISSION; HOWEVER, THE MAGNITUDE OF INDIVIDUAL SUBSYSTEM UNSCHEDULED M&R TOGETHER WITH RELATED SKILL REQUIREMENTS WILL VARY.

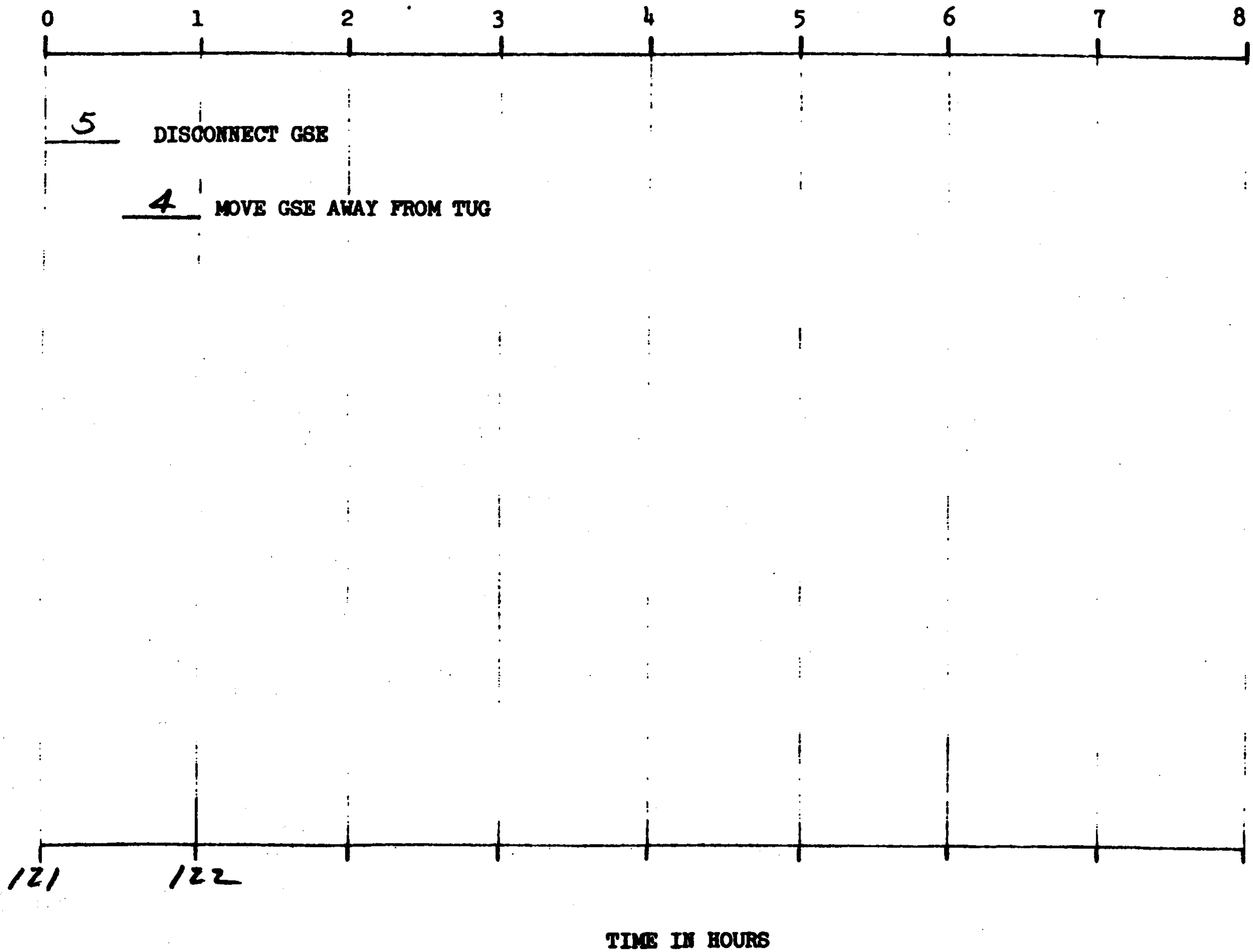
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I KSC	POST M&R VERIFICATION	1.2.1



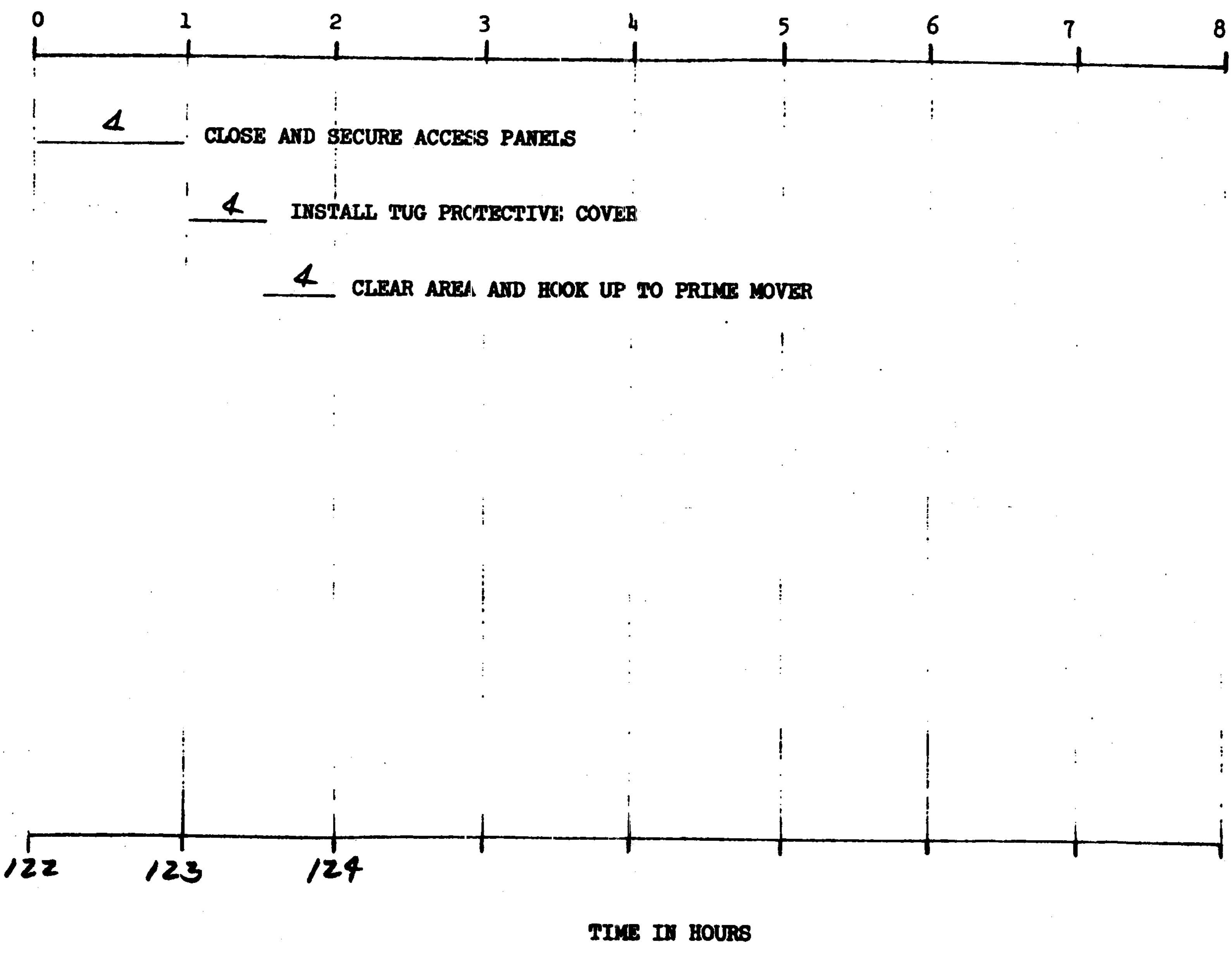
OPTION NUMBER 3I KSC	FUNCTION TITLE PERFORM POST M&R VERIFICATION - FSE	FLOW BLOCK NO. 1.2.2



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I KSC	REMOVE M&R GSE	1.1.14



OPTION NUMBER 3I KSC	FUNCTION TITLE PREPARE FOR TRANSPORT	FLOW BLOCK NO. 1.1.2 1



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I KSC	TRANSFER TO PRELAUNCH	1.1.2 6

0 1 2 3 4 5 6 7 8

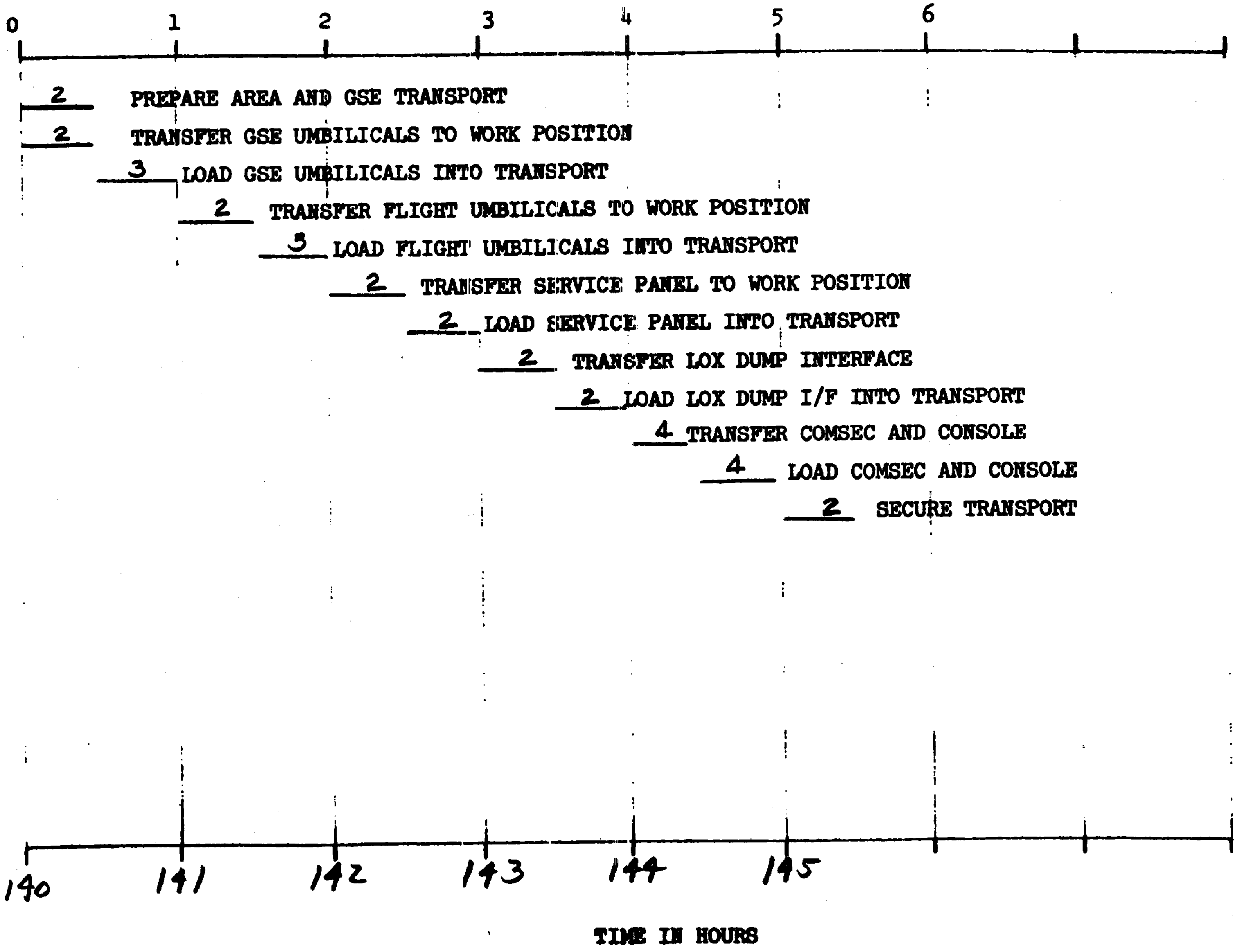
4 TRANSPORT TUG FROM TPF (OR PPF) TO PRELAUNCH AREA

4 POSITION TUG IN PRELAUNCH AREA AND REMOVE TUG PROTECTION COVER

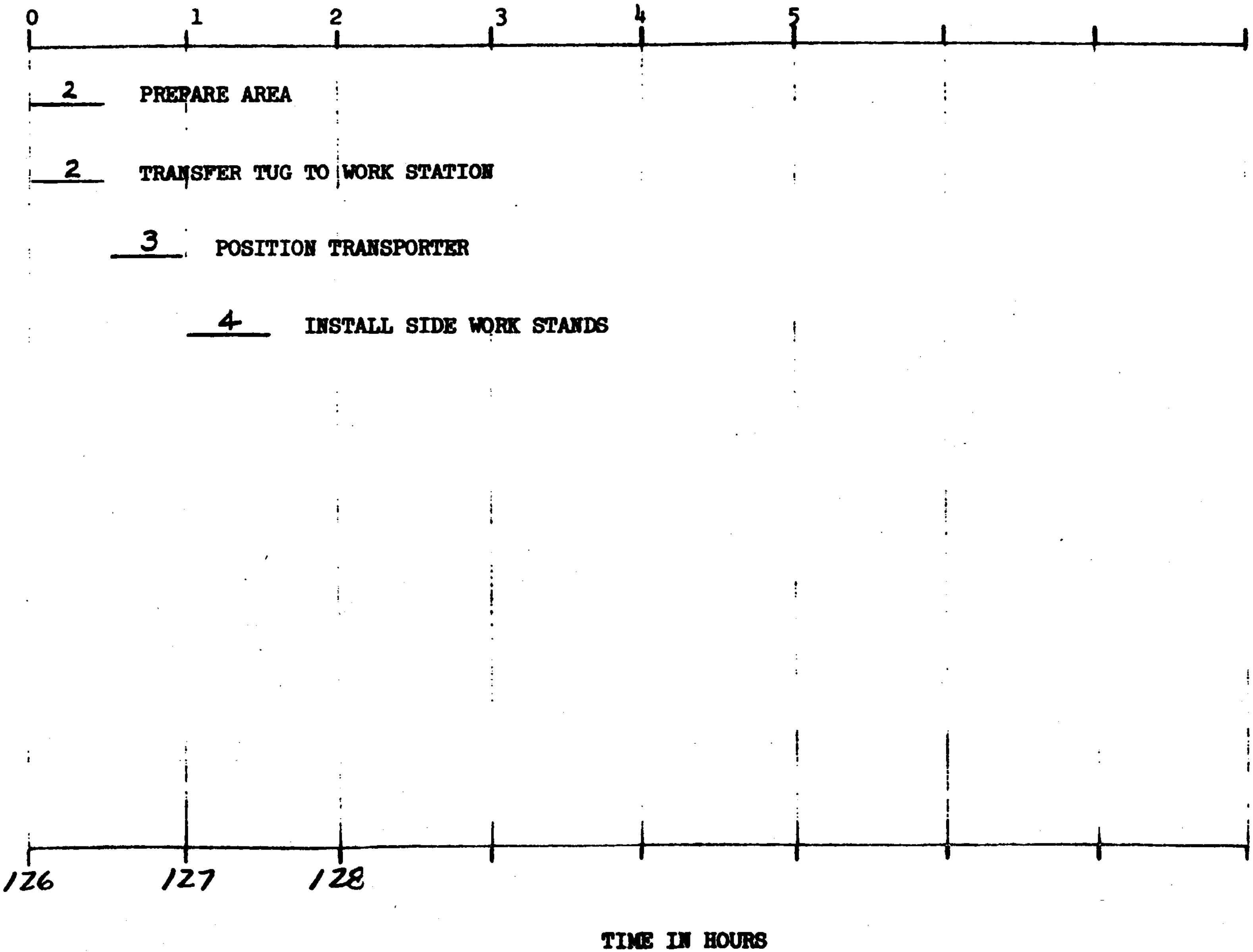
124 125 126

TIME IN HOURS

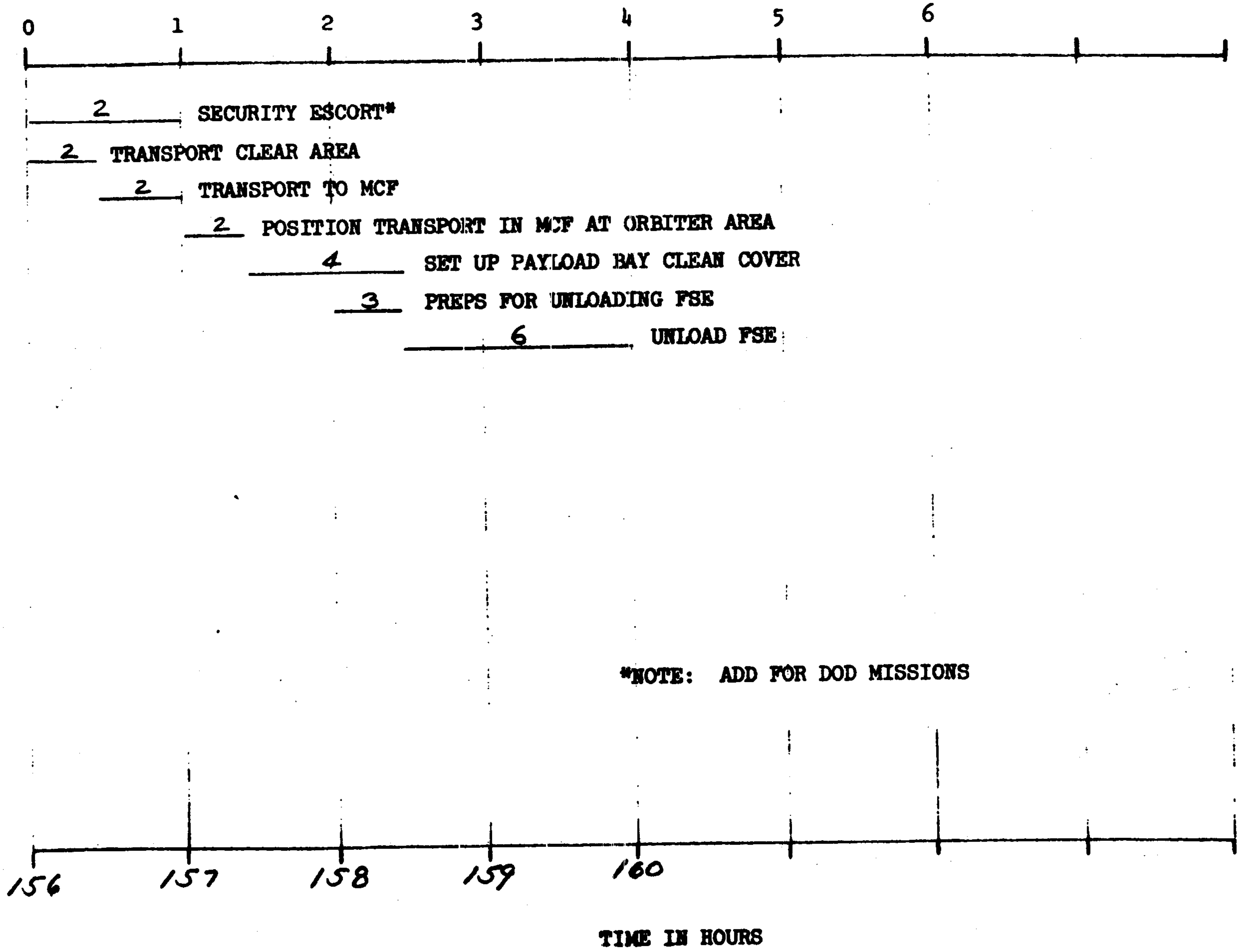
OPTION NUMBER	3I KSC	FUNCTION TITLE	RECEIVE FSE FROM M&R	FLOW BLOCK NO.	2.1.1



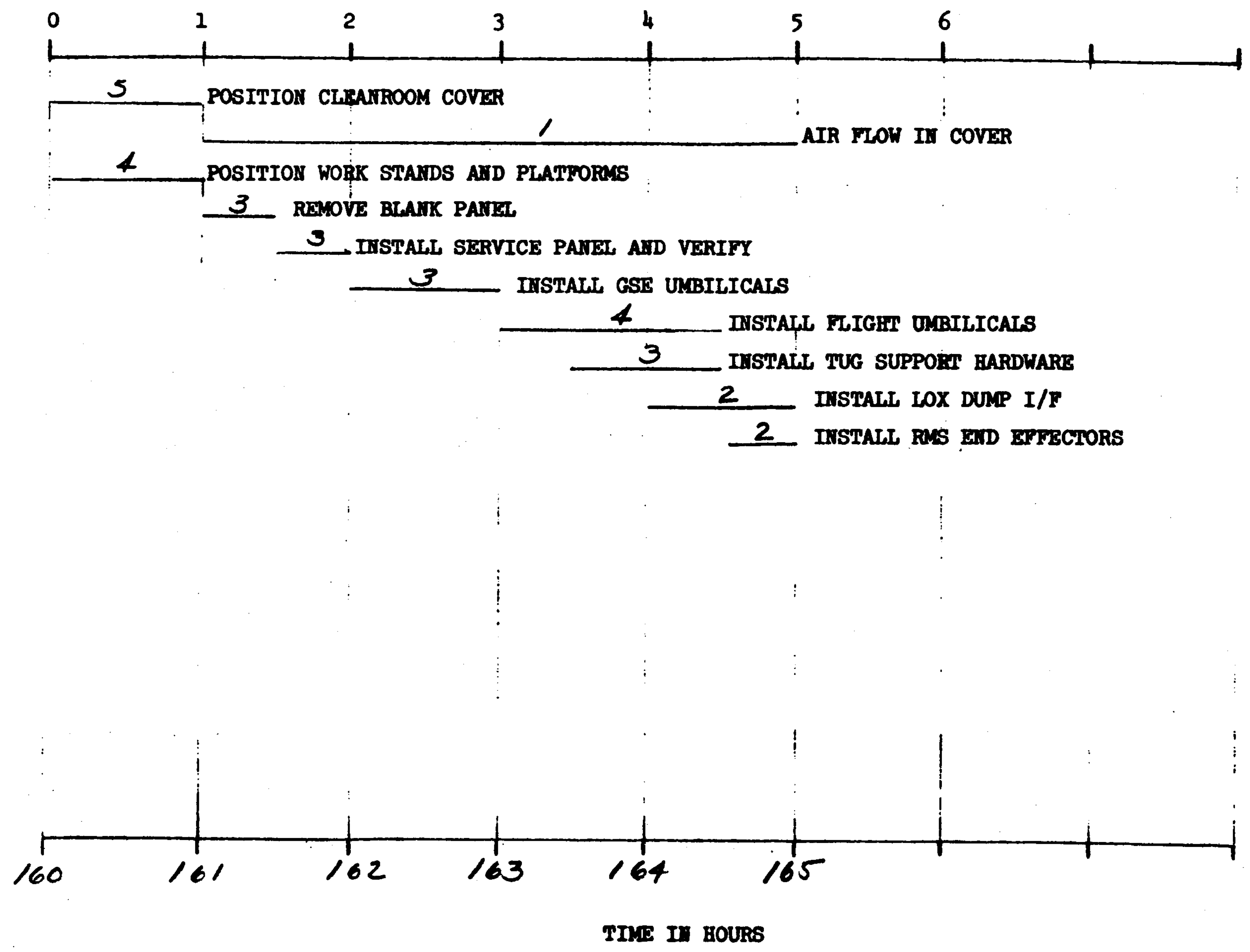
OPTION NUMBER 3I KSC	FUNCTION TITLE RECEIVE TUG FROM M&R	FLOW BLOCK NO. 2.1.2



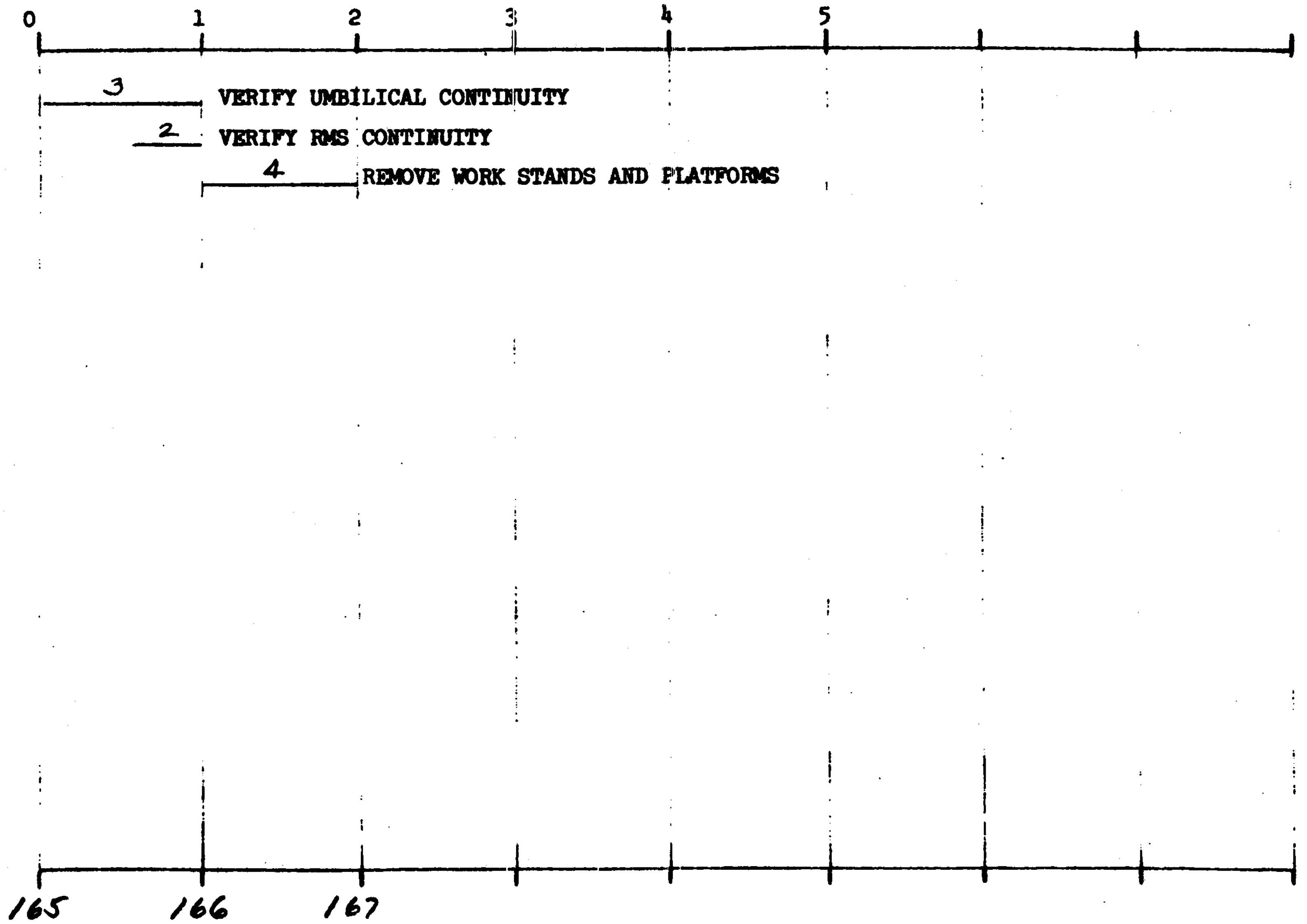
OPTION NUMBER 3I KSC	FUNCTION TITLE TRANSFER FSE TO MCF	FLOW BLOCK NO. 2.3.1



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I KSC	INSTALL FSE IN PAYLOAD BAY	2.3.2.2

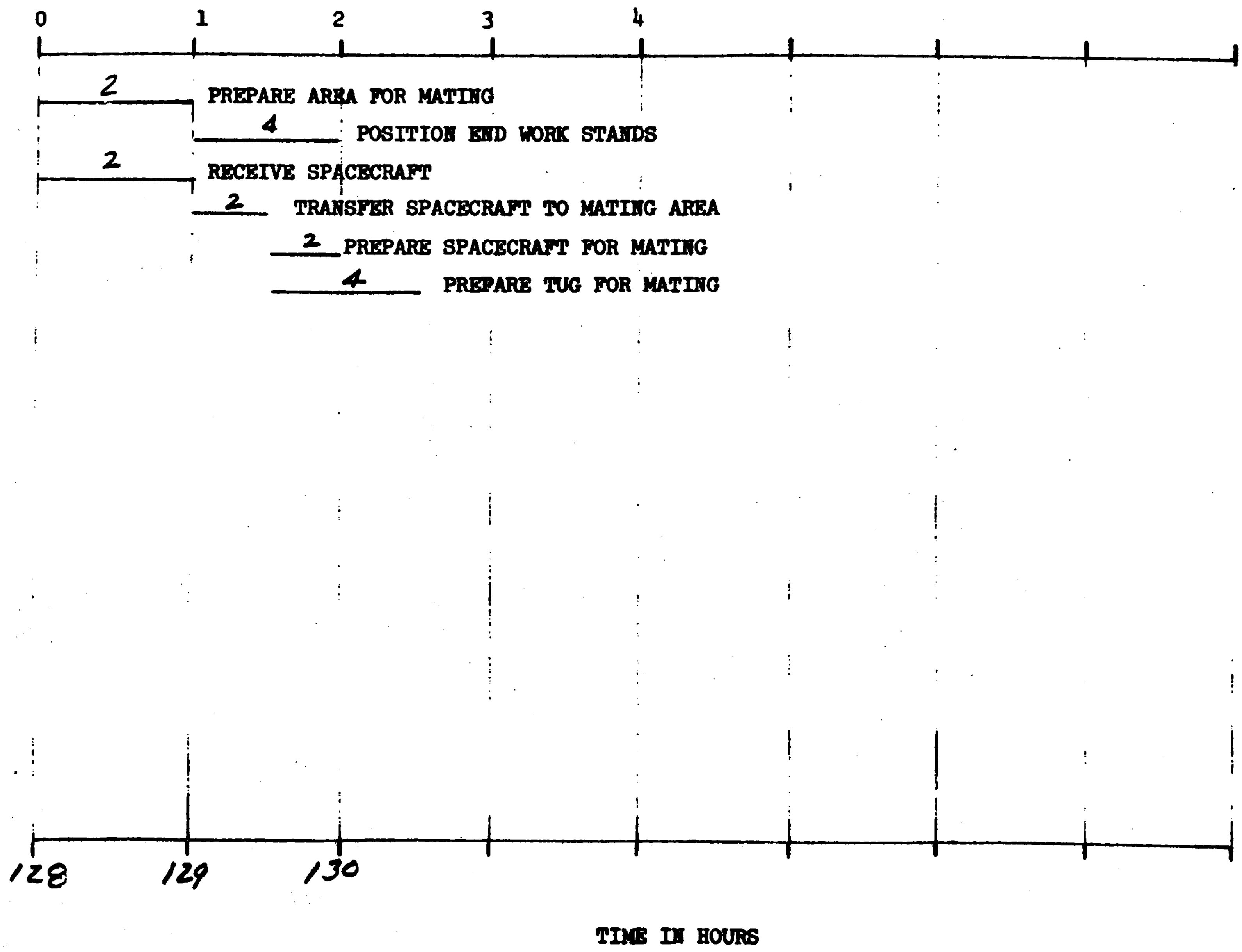


OPTION NUMBER 3I KSC	FUNCTION TITLE VERIFY FSE INTERFACES	FLOW BLOCK NO. 2.3.3



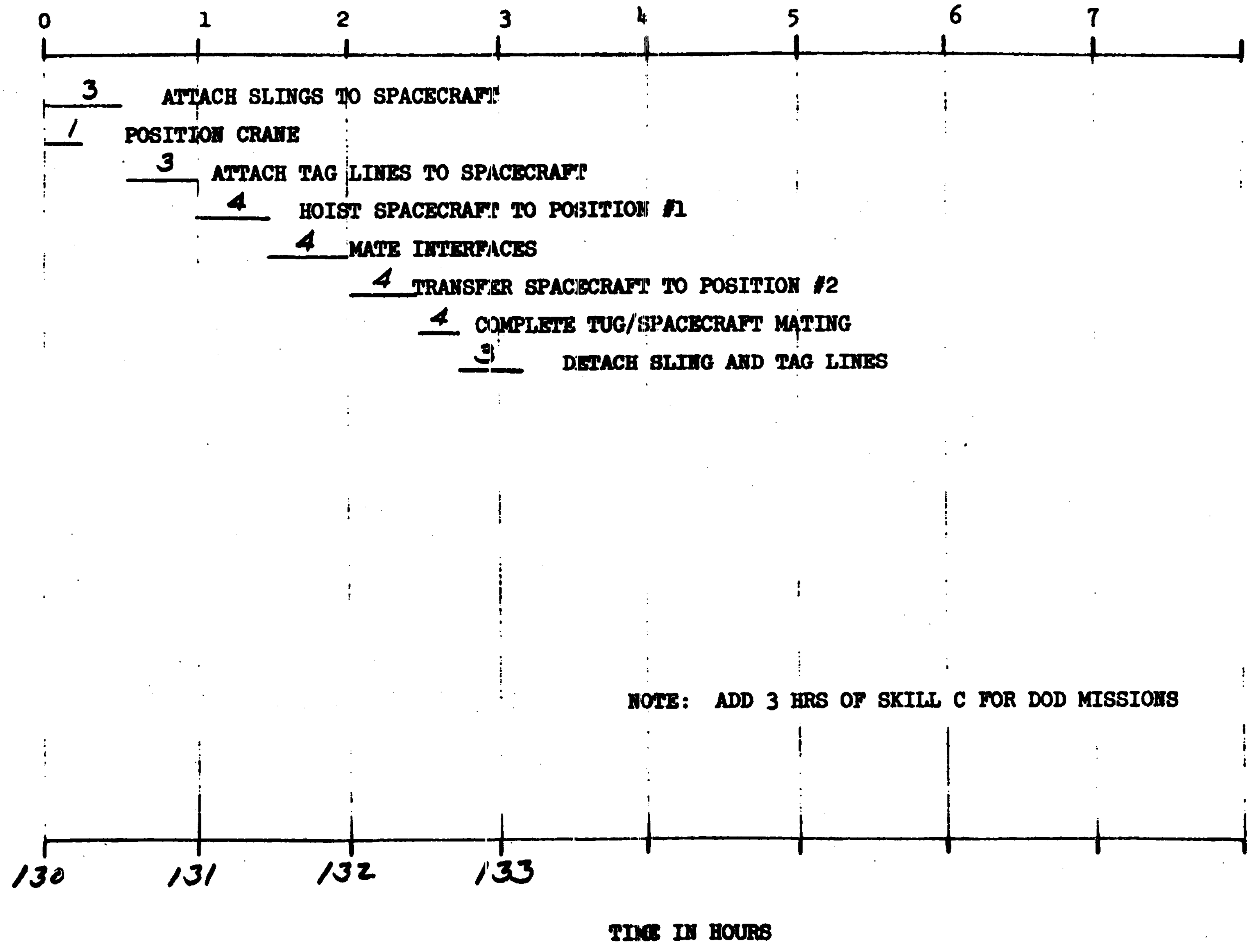
TIME IN HOURS

OPTION NUMBER 3I KSC	FUNCTION TITLE PREPARE TUG FOR SPACECRAFT	FLOW BLOCK NO. 2.2.2.a

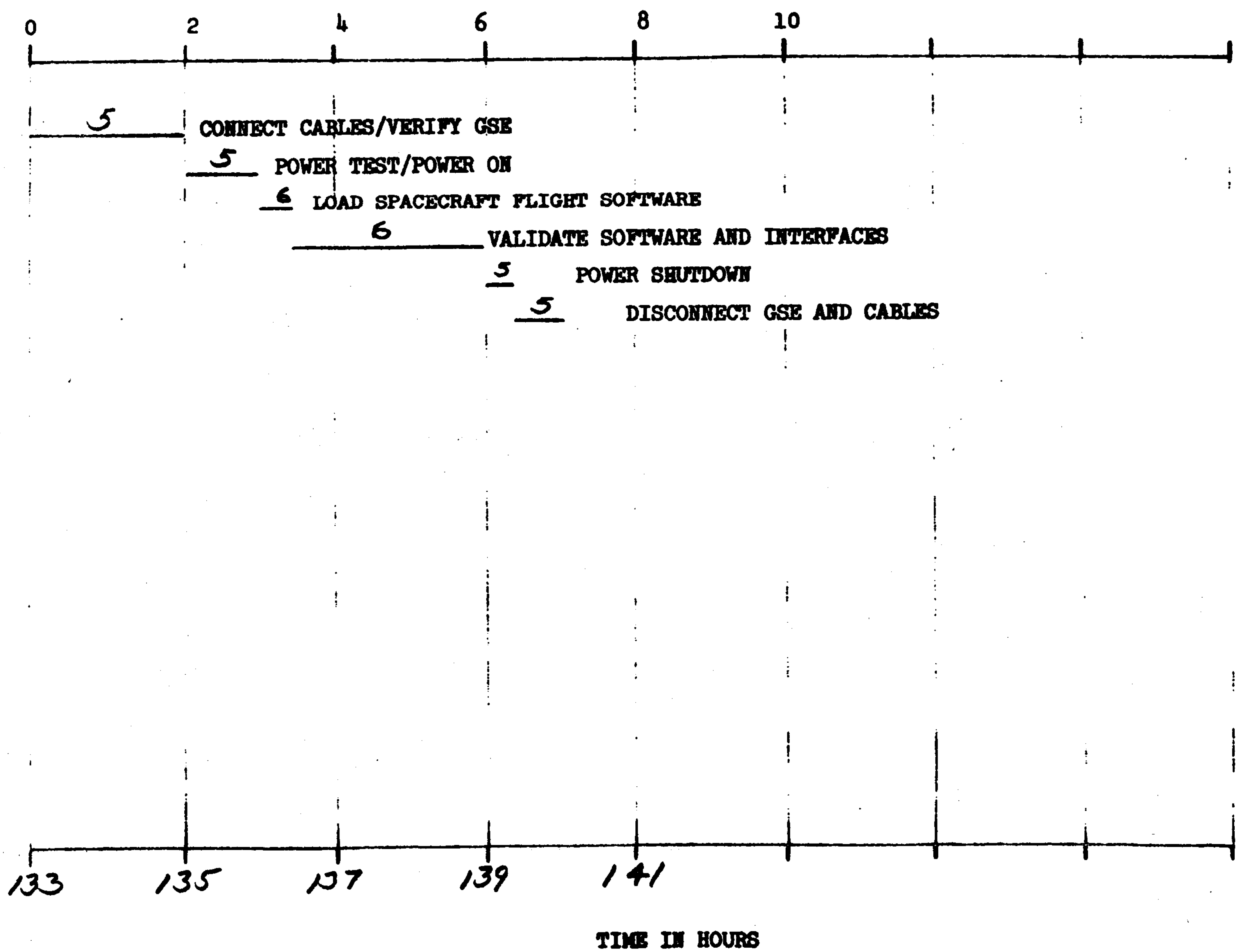


NOTE: NO KICK STAGE

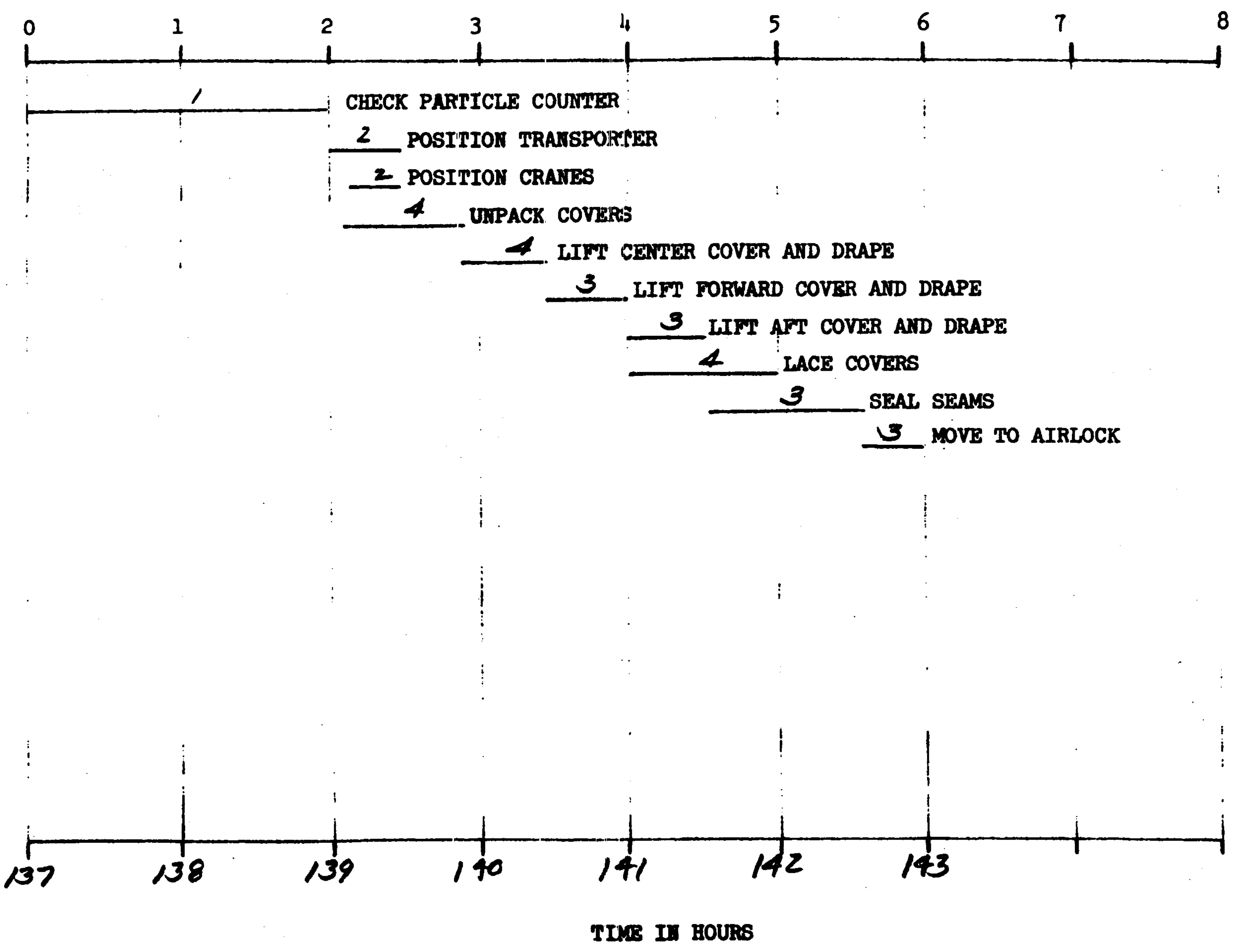
OPTION NUMBER 3I KSC	FUNCTION TITLE MATE TUG AND SPACECRAFT	FLOW BLOCK NO. 2.2.3



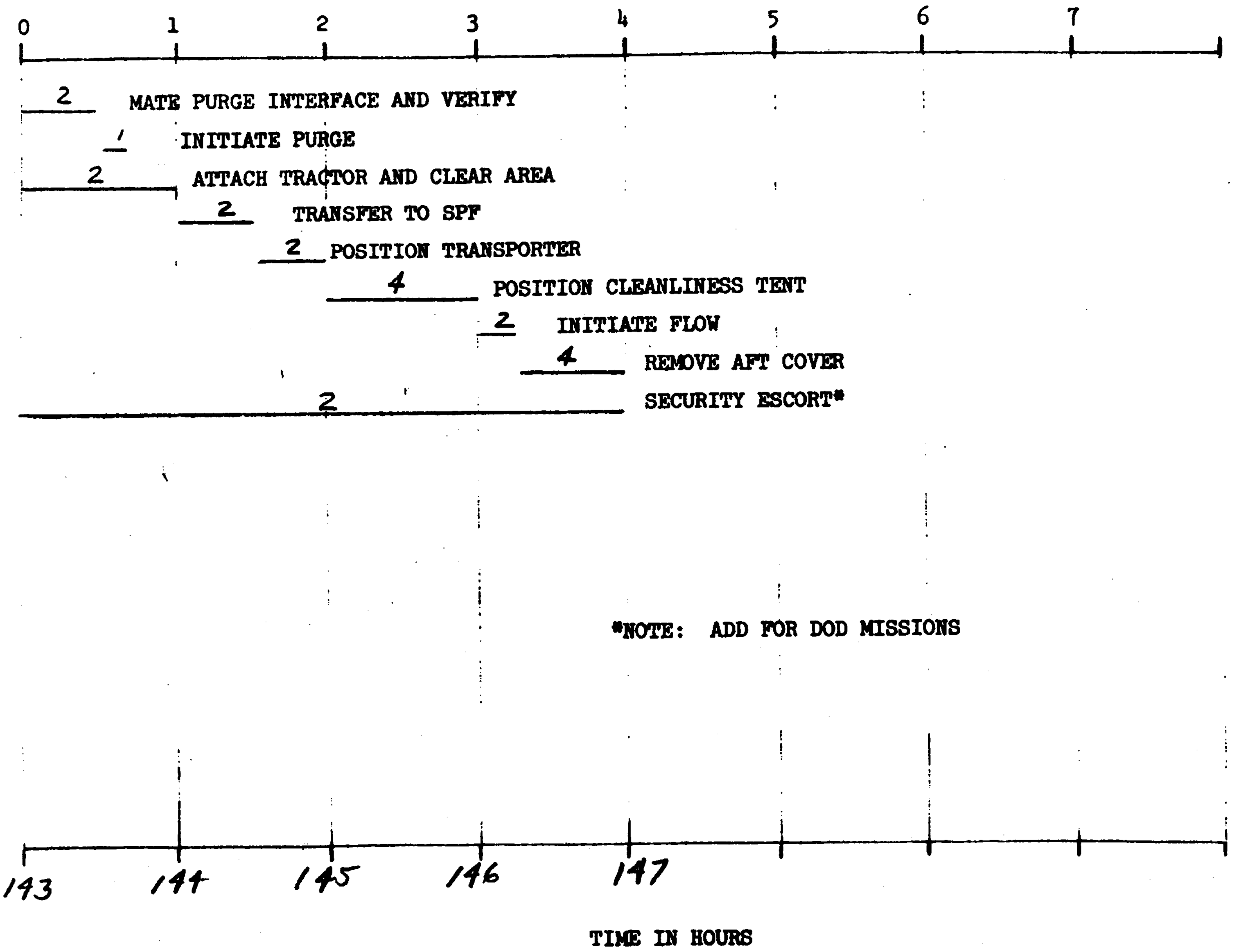
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I KSC	VERIFY TUG-TO-SPACECRAFT INTERFACES	2.2.4



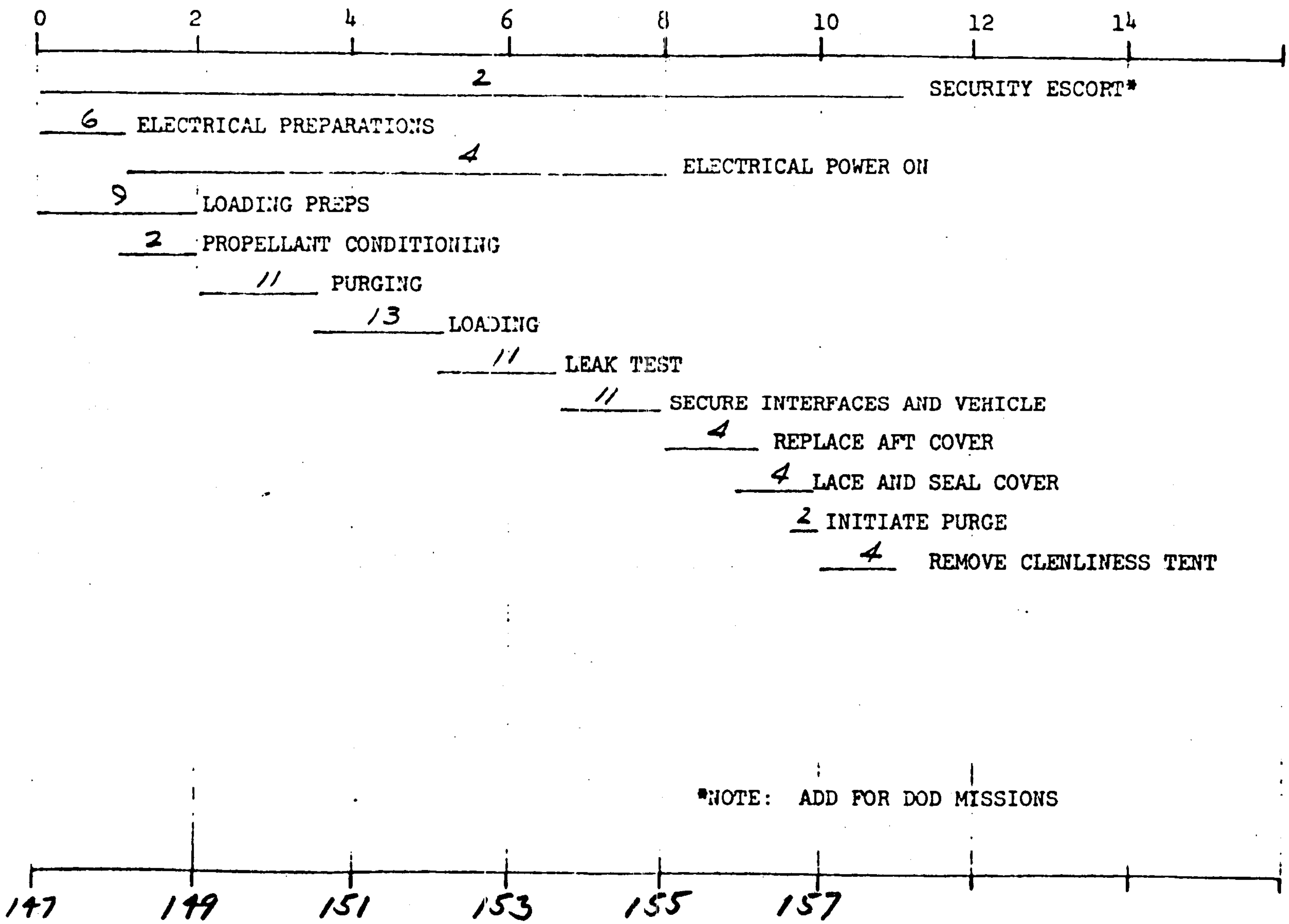
OPTION NUMBER 3I KSC	FUNCTION TITLE VERIFY CLEANLINESS	FLOW BLOCK NO. 2.2.5



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I KSC	TRANSFER PAYLOAD TO SPF	2.1.5



OPTION NUMBER 3I KSC	FUNCTION TITLE STORABLE PROPELLANT SERVICING	FLOW BLOCK NO. 2.1.7

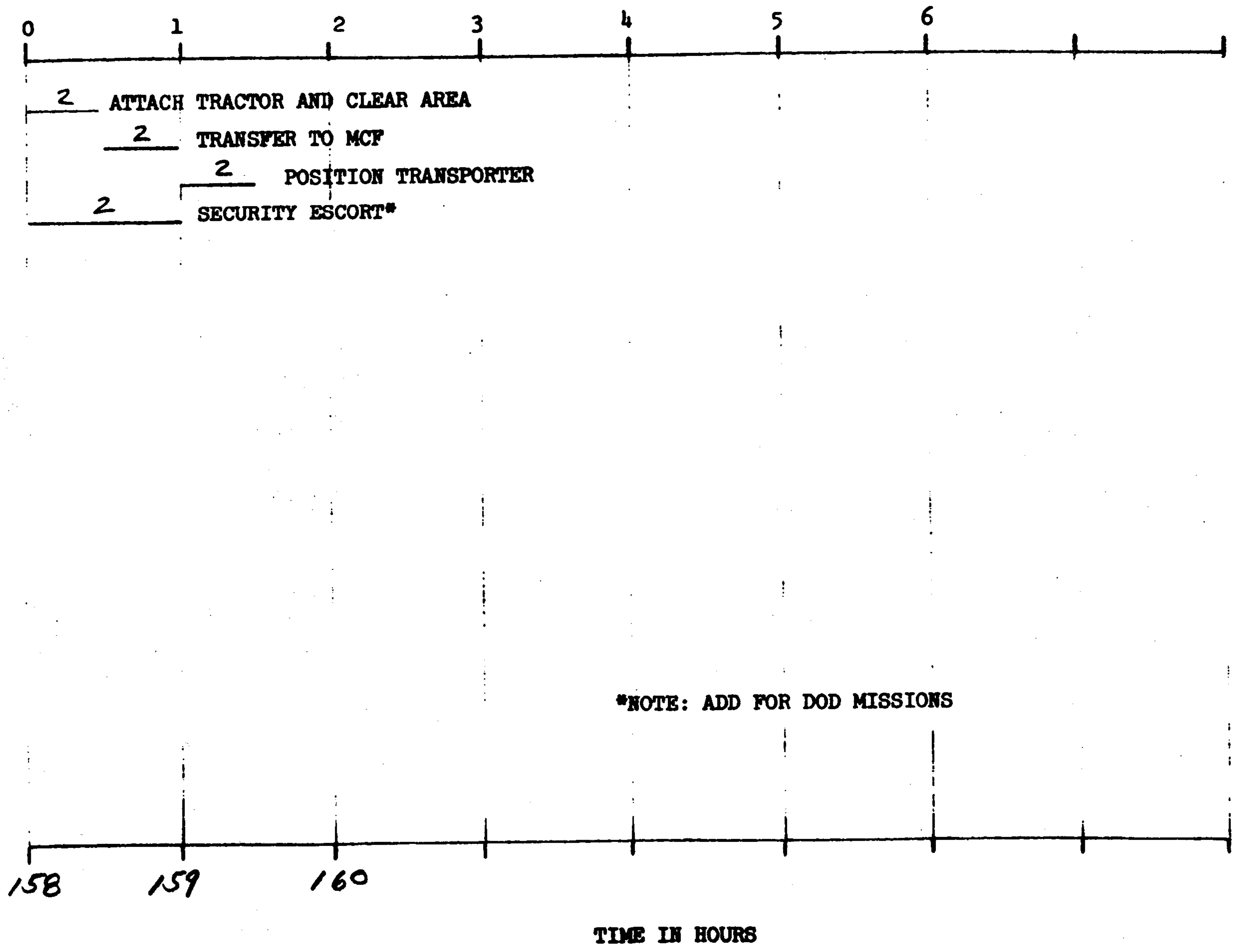


*NOTE: ADD FOR DOD MISSIONS

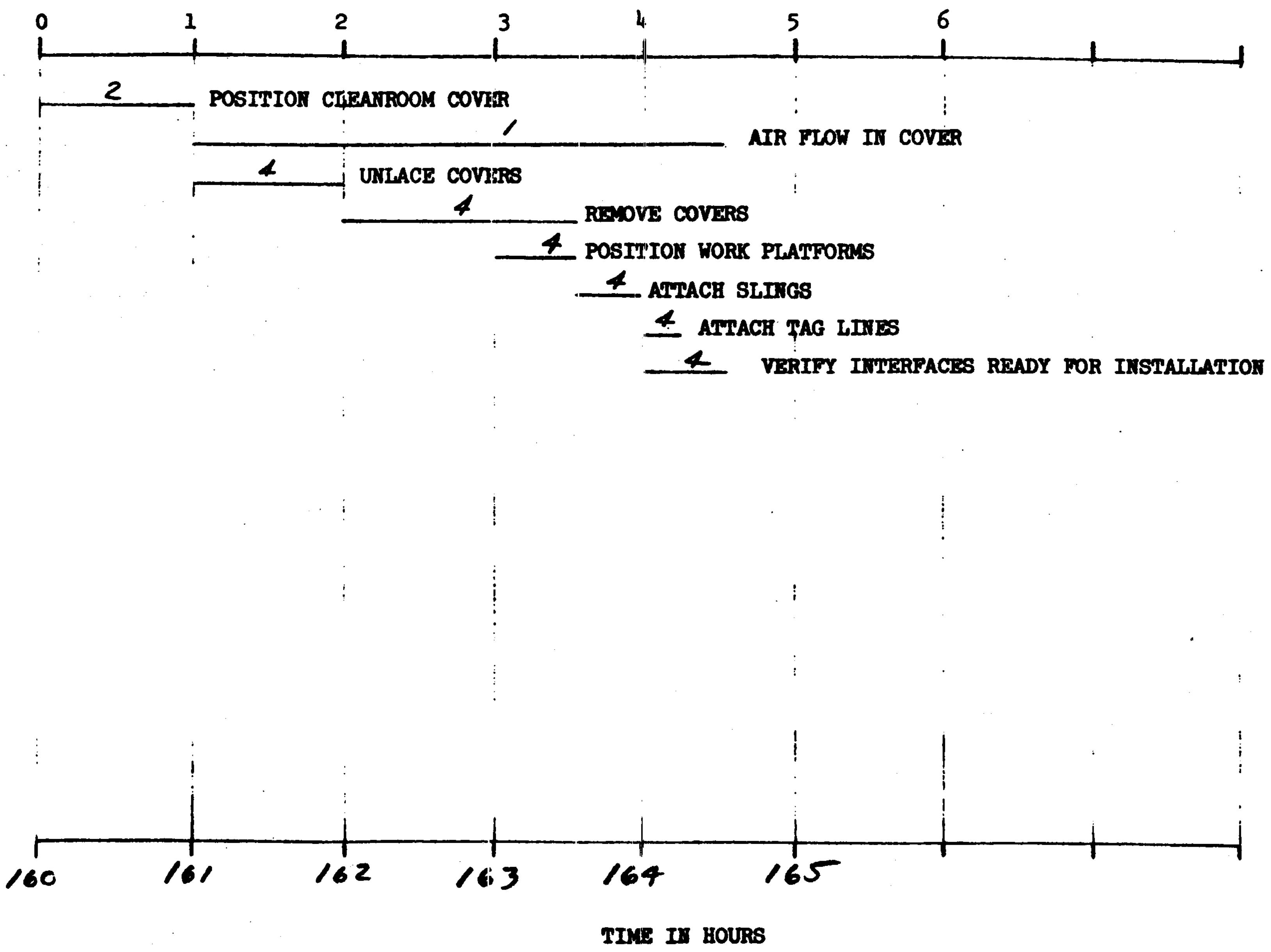
TIME IN HOURS

NOTE: MONOPROPELLANT AT SPF

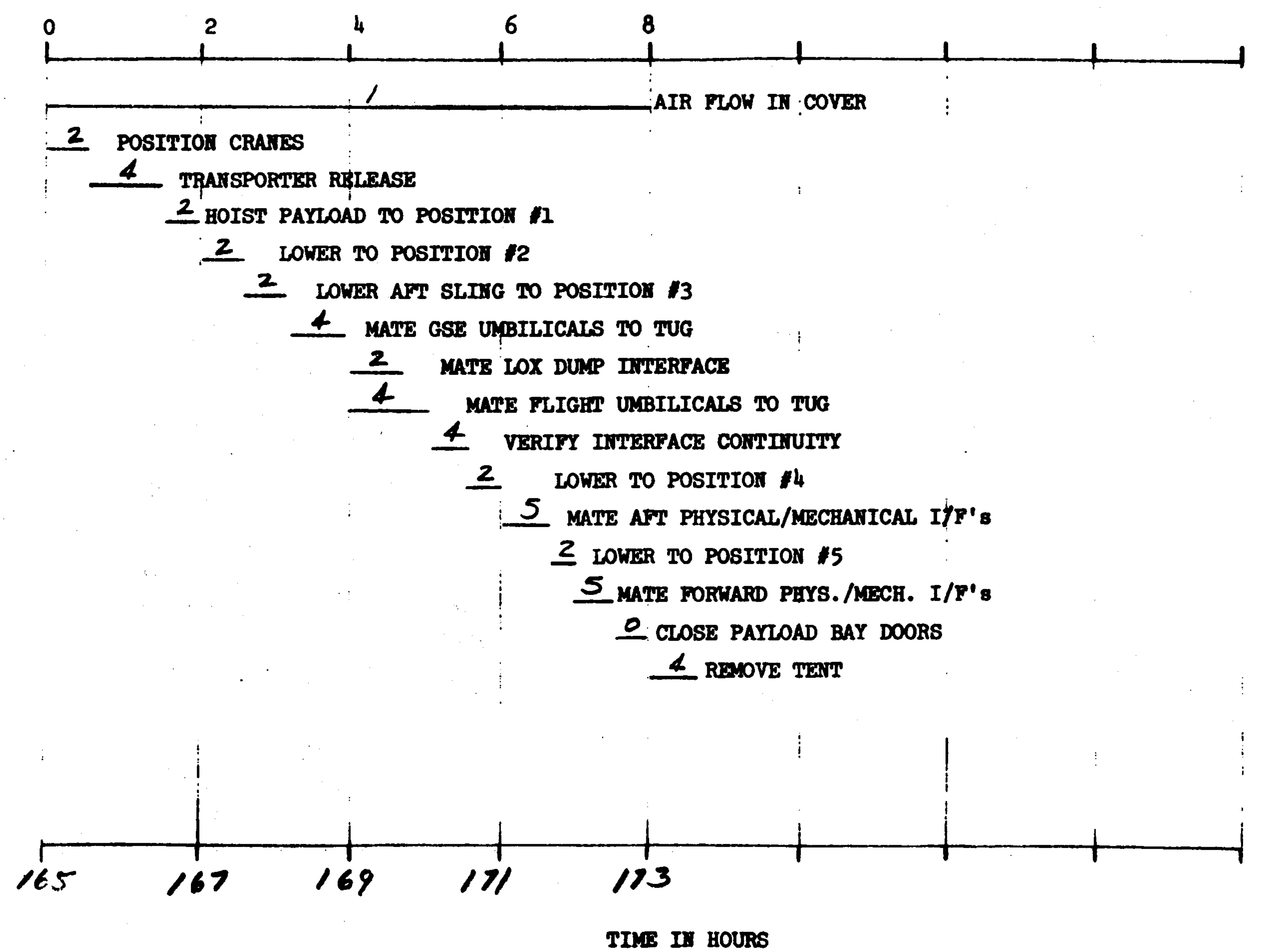
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I KSC	TRANSFER PAYLOAD TO MCF	2.3.4



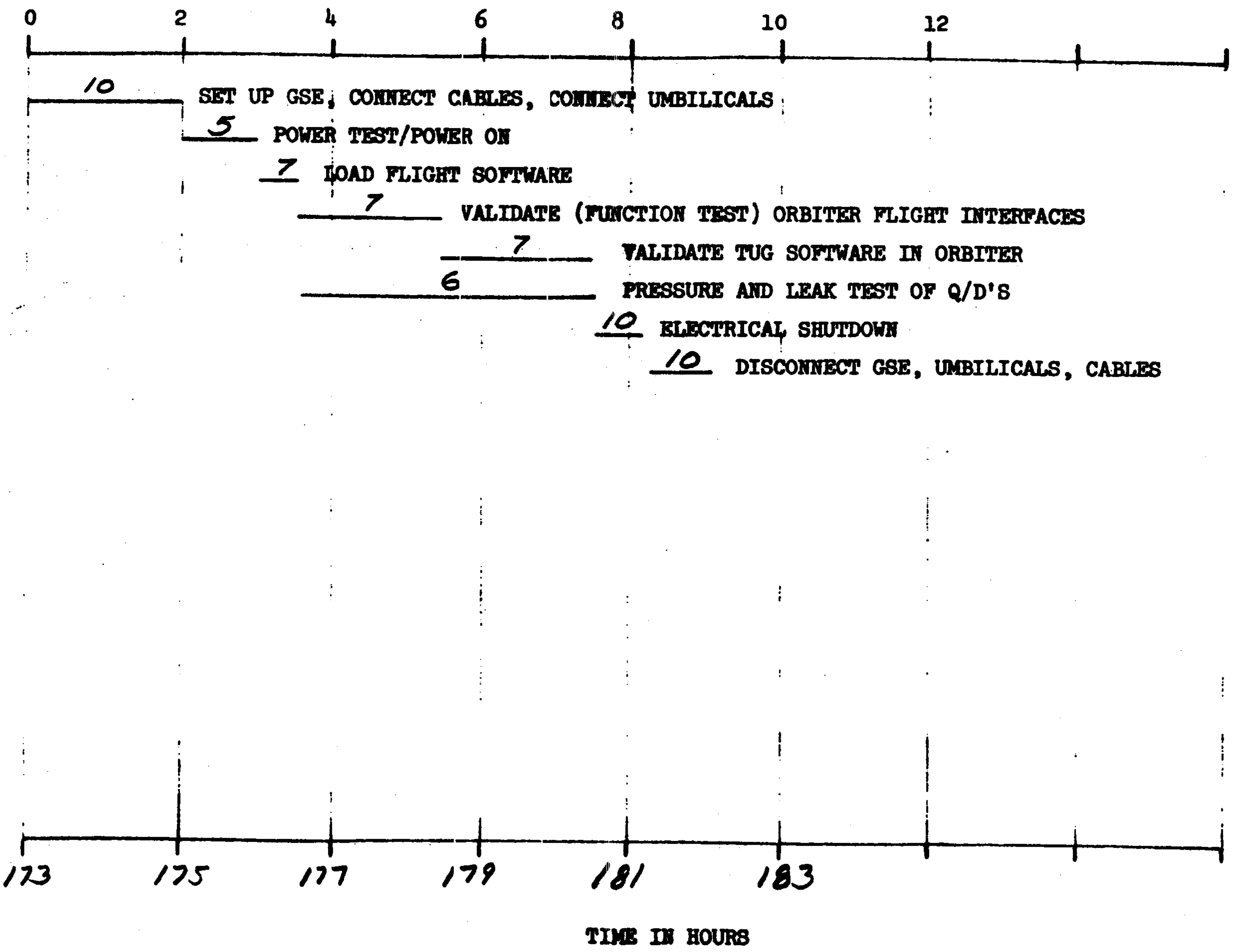
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3I KSC	PAYLOAD INSTALLATION PREPS	2.3.6



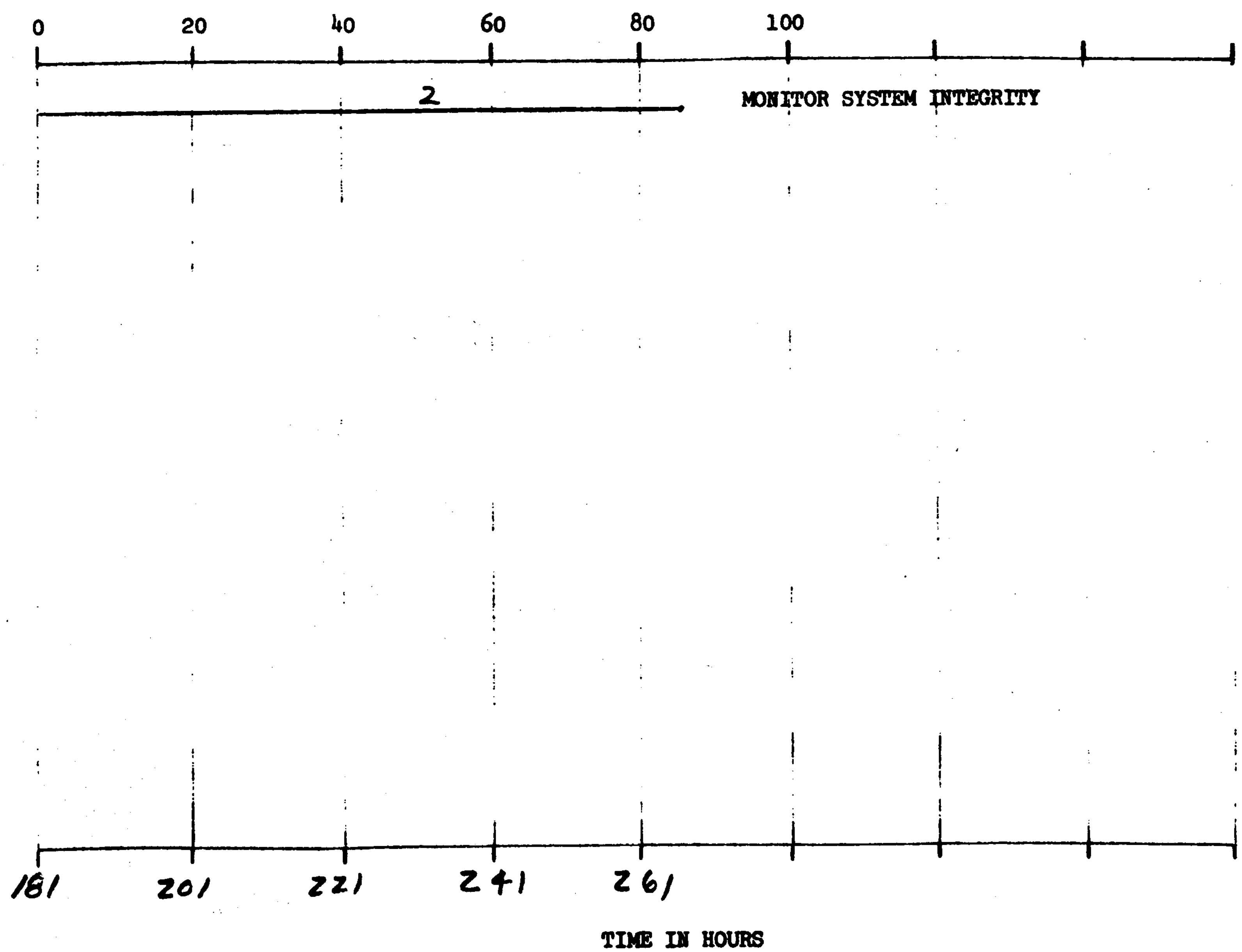
OPTION NUMBER 3I KSC	FUNCTION TITLE PAYLOAD INSTALLATION MCF	FLOW BLOCK NO. 2.3.7



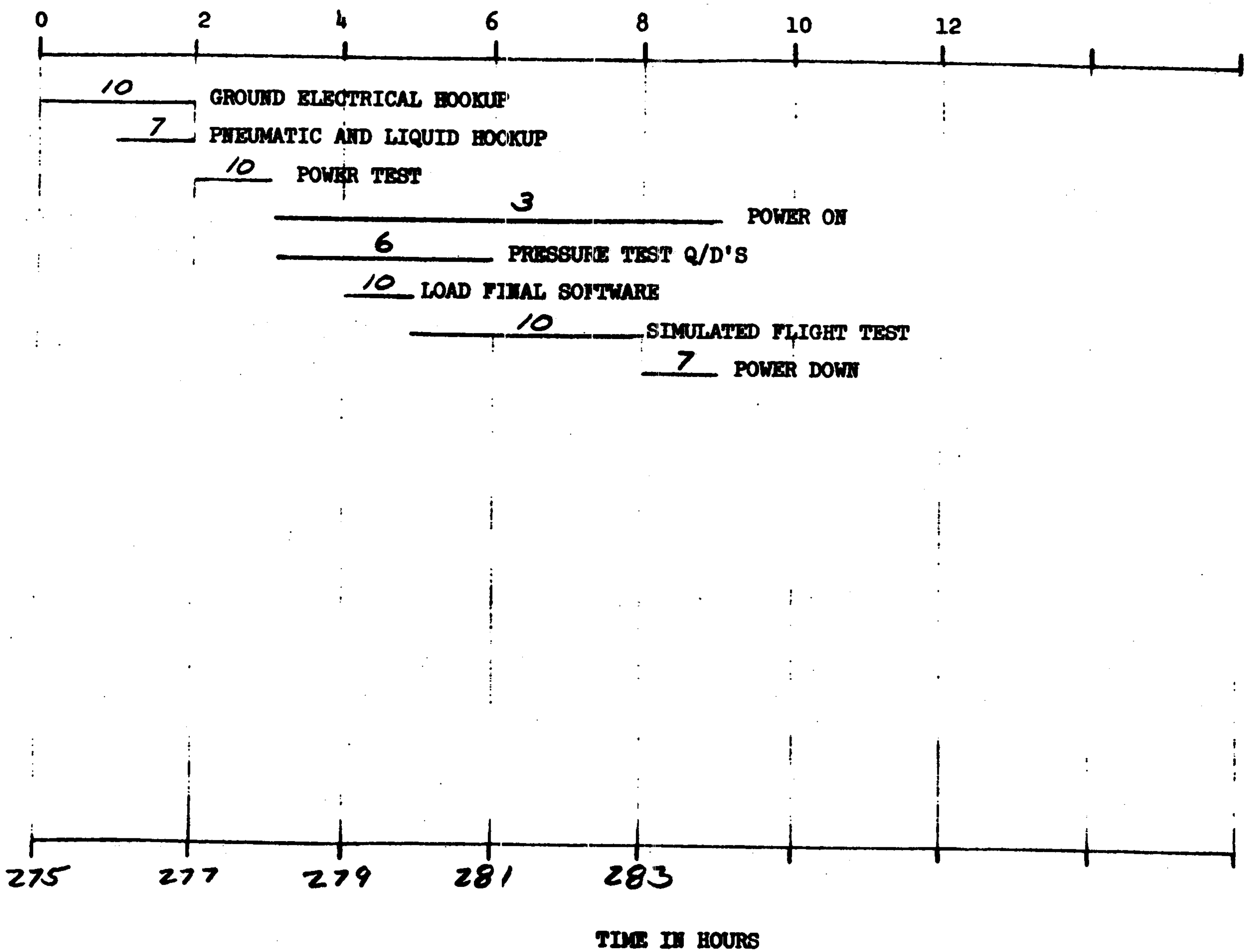
OPTION NUMBER 3I KSC	FUNCTION TITLE VERIFY PAYLOAD-TO-SHUTTLE INTERFACES	FLOW BLOCK NO. 2.3.9



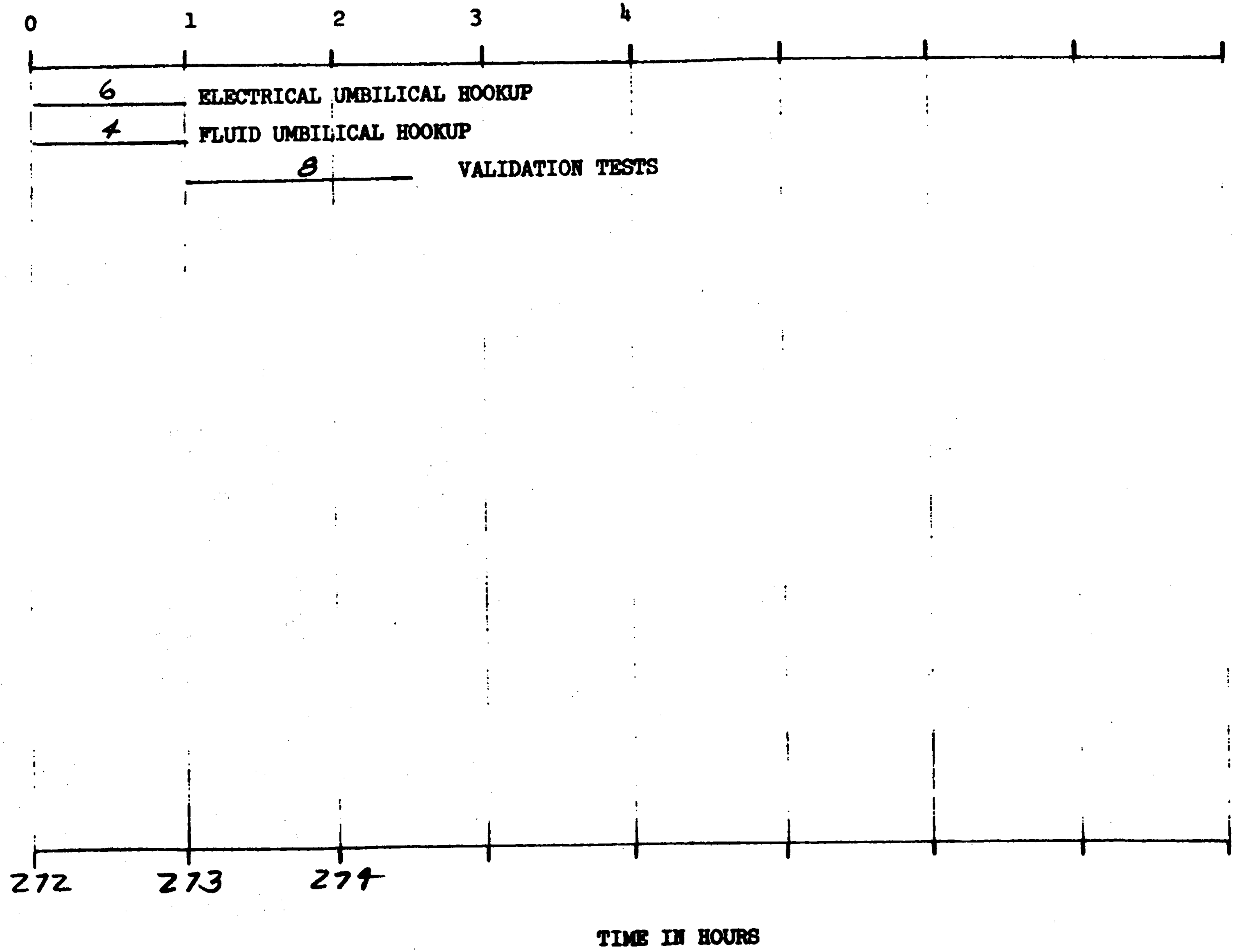
OPTION NUMBER 3I KSC	FUNCTION TITLE MONITOR STORABLE ACPS	FLOW BLOCK NO. 2.4.1.a



OPTION NUMBER 3I KSC	FUNCTION TITLE ORBITER/PAYLOAD INTEGRATION SYSTEM TEST	FLOW BLOCK NO. 2.4.1

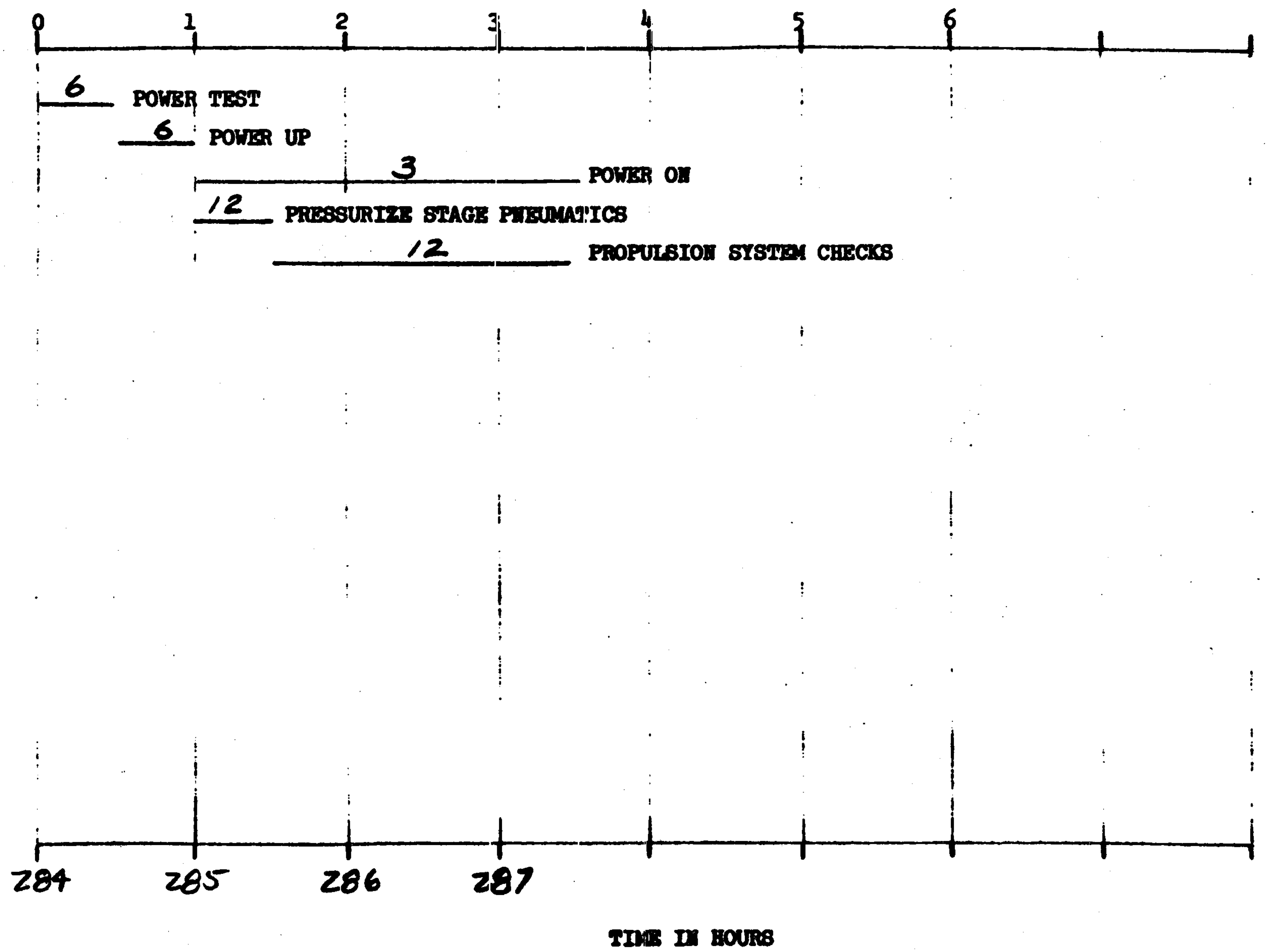


OPTION NUMBER 3I KSC	FUNCTION TITLE TUG SERVICE AT PAD (NON-CRYOS)	FLOW BLOCK NO. 2.4.2.a

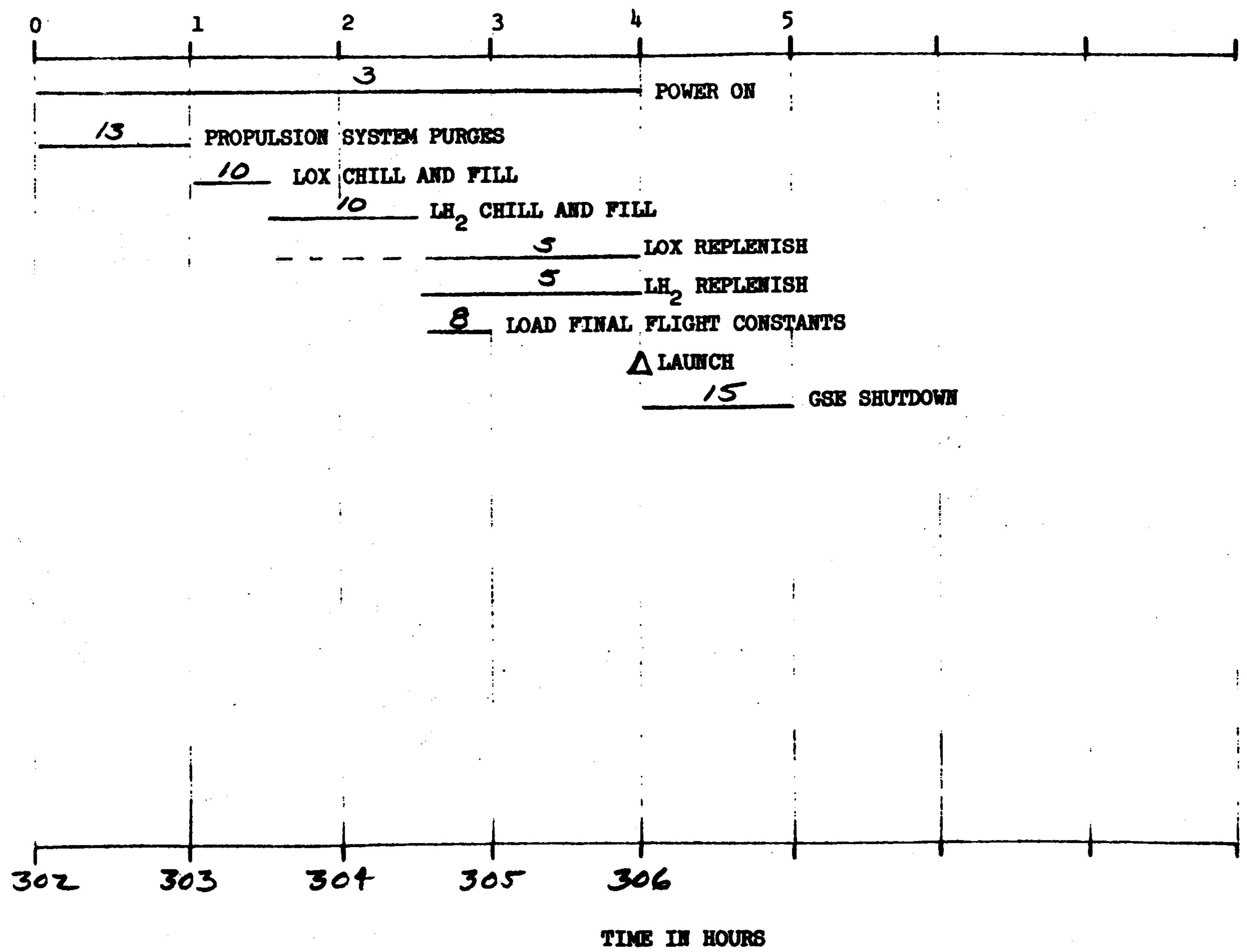


MBILICAL HOOKUP

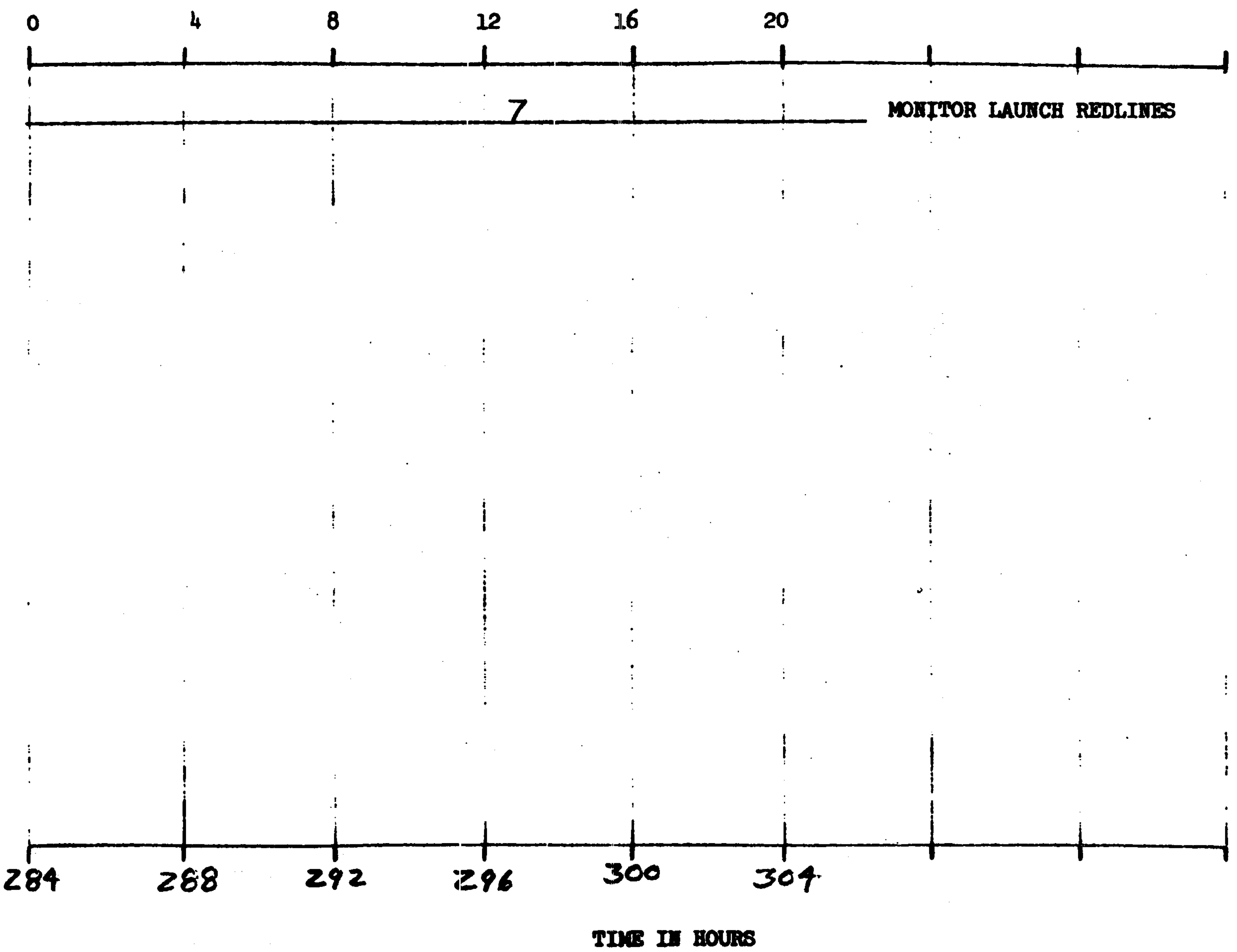
OPTION NUMBER 3I KSC	FUNCTION TITLE TUG SERVICE AT PAD (NON-CRYO)	FLOW BLOCK NO. 2.4.2.b



OPTION NUMBER 3I KSC	FUNCTION TITLE TUG SERVICE AT PAD (CRYO'S)	FLOW BLOCK NO. 2.4.3



OPTION NUMBER 3I KSC	FUNCTION TITLE SUBSYSTEM MONITORING AT PAD	FLOW BLOCK NO. 2.4.4



TASK TIMELINES

FOR

THE CRYOGENIC TUG

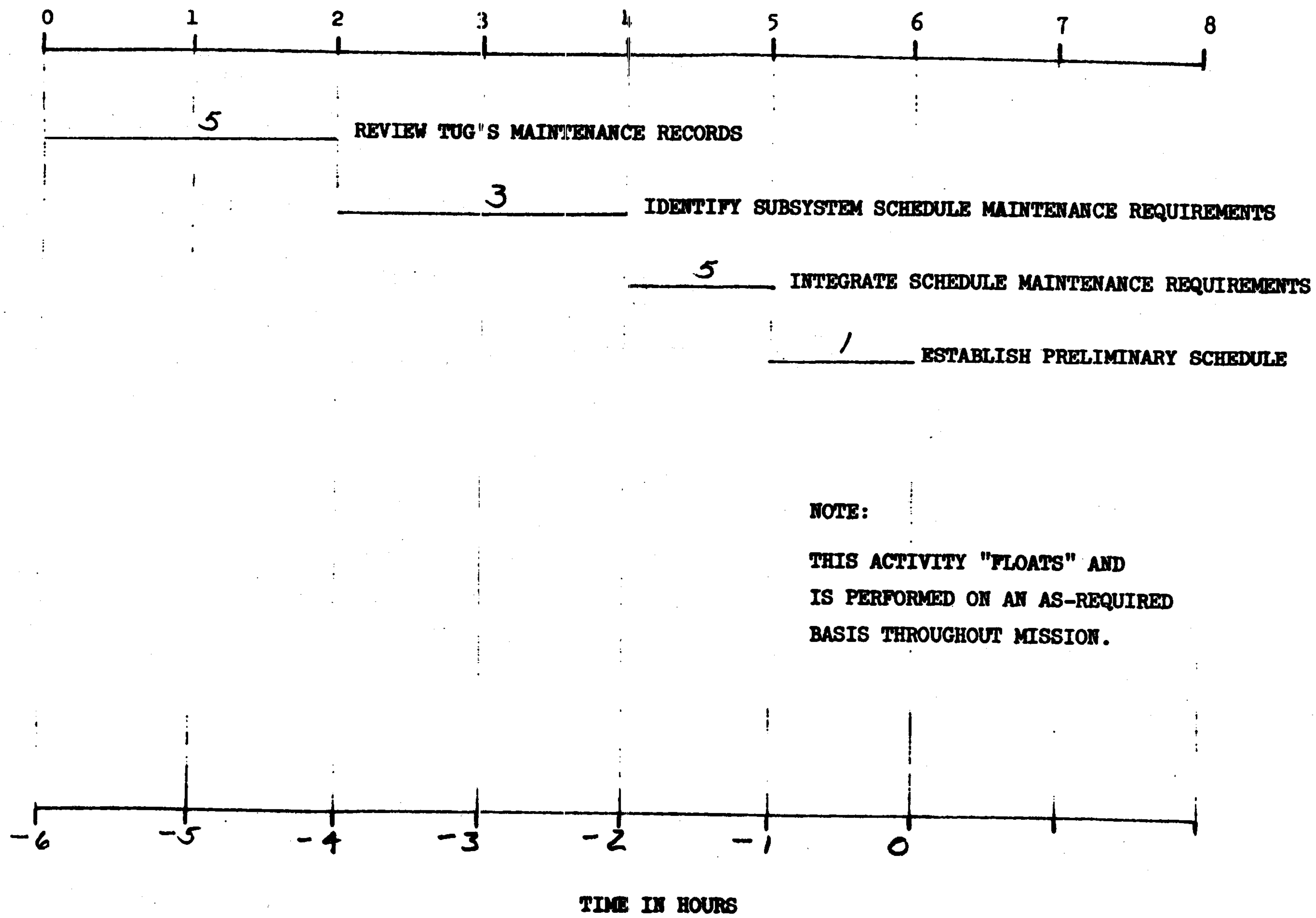
GROUND AND LAUNCH OPERATIONS

OPTION NO. 3F ETR

SEPTEMBER 1973

11-222

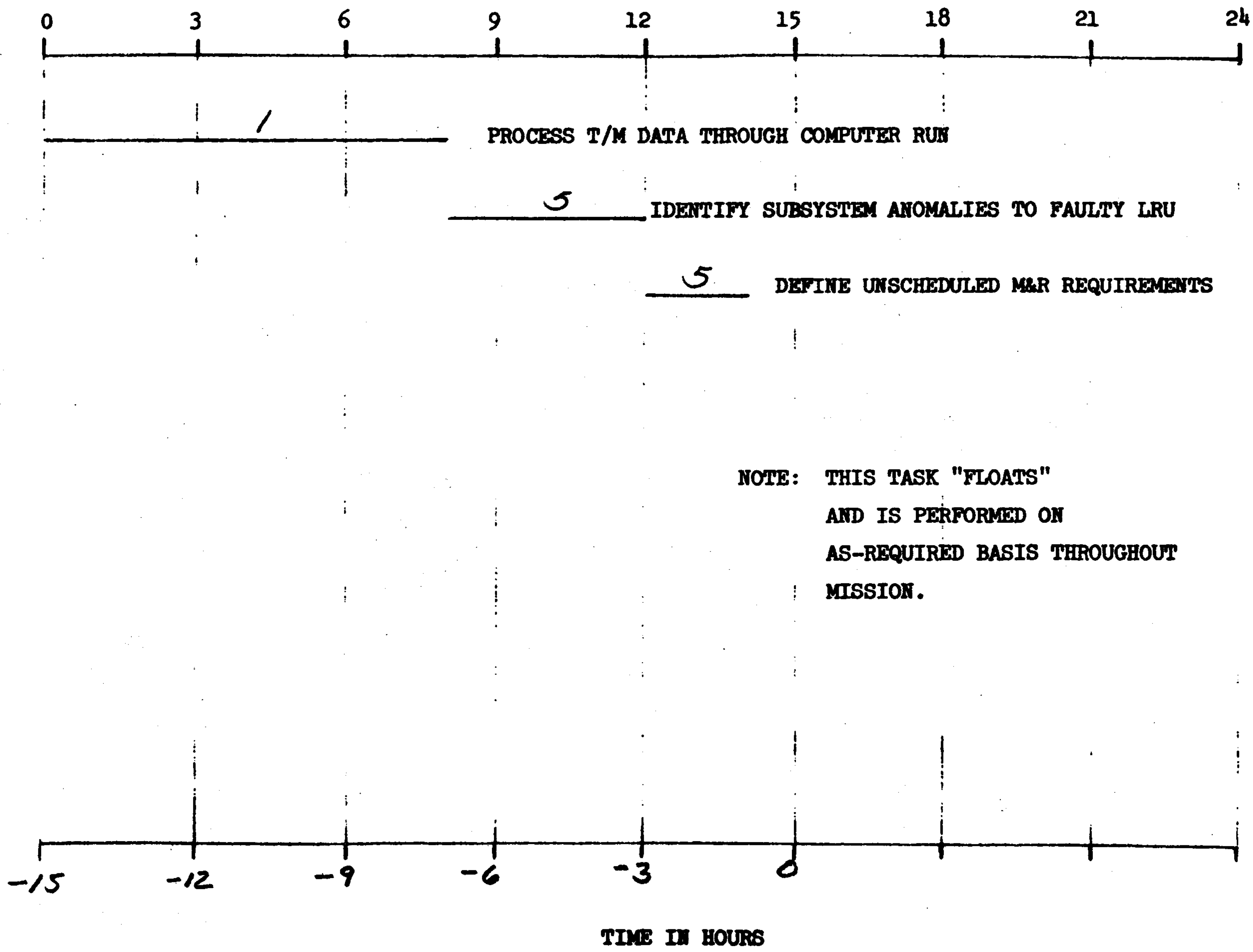
OPTION NUMBER 3F KSC	FUNCTION TITLE PREPARE PRELIMINARY M&R SCHEDULE	FLOW BLOCK NO. 1.1.1



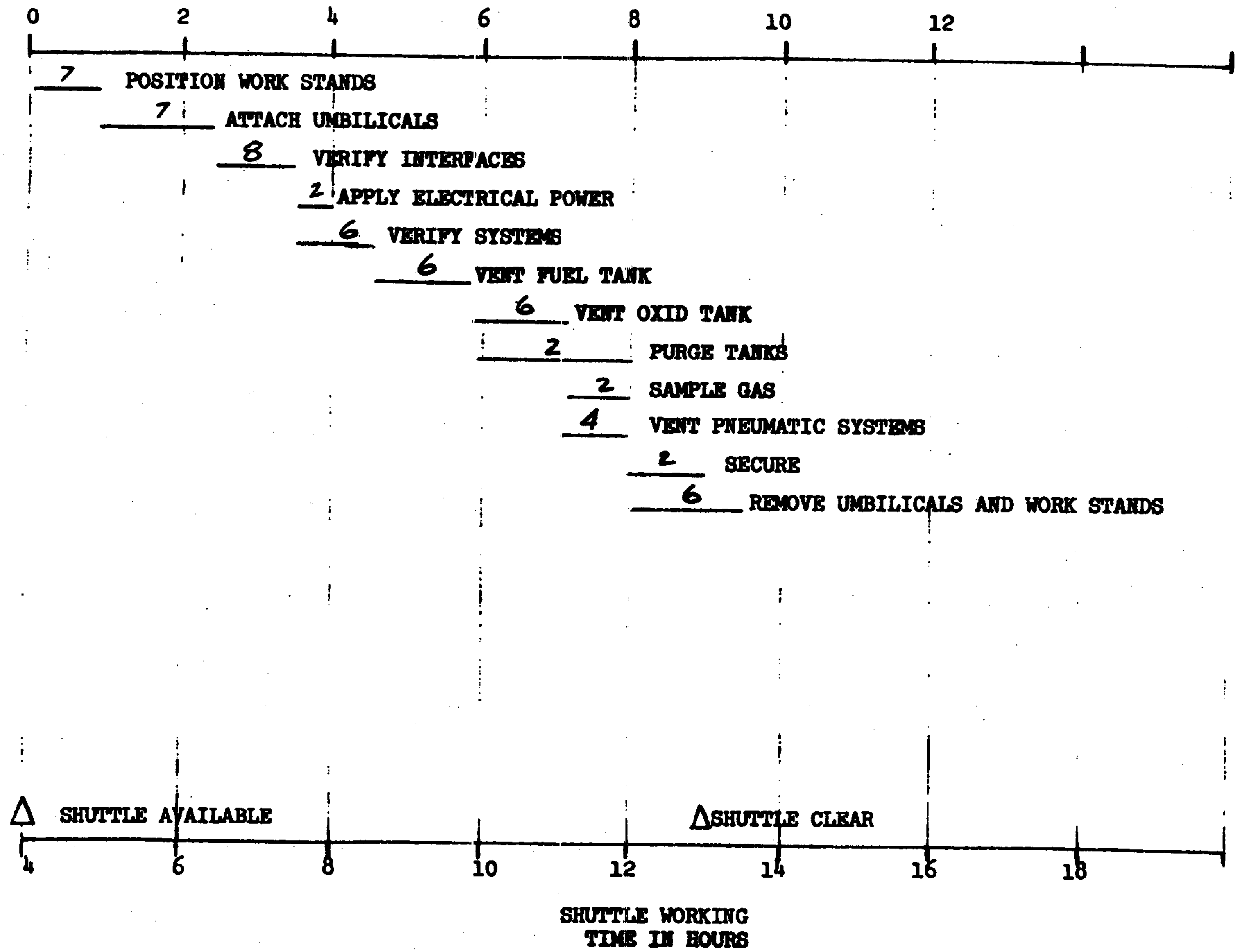
NOTE:

THIS ACTIVITY "FLOATS" AND IS PERFORMED ON AN AS-REQUIRED BASIS THROUGHOUT MISSION.

OPTION NUMBER 3F KSC	FUNCTION TITLE	ANALYZE T/M FOR UNSCHEDULE M&R	FLOW BLOCK NO. 1.1.2



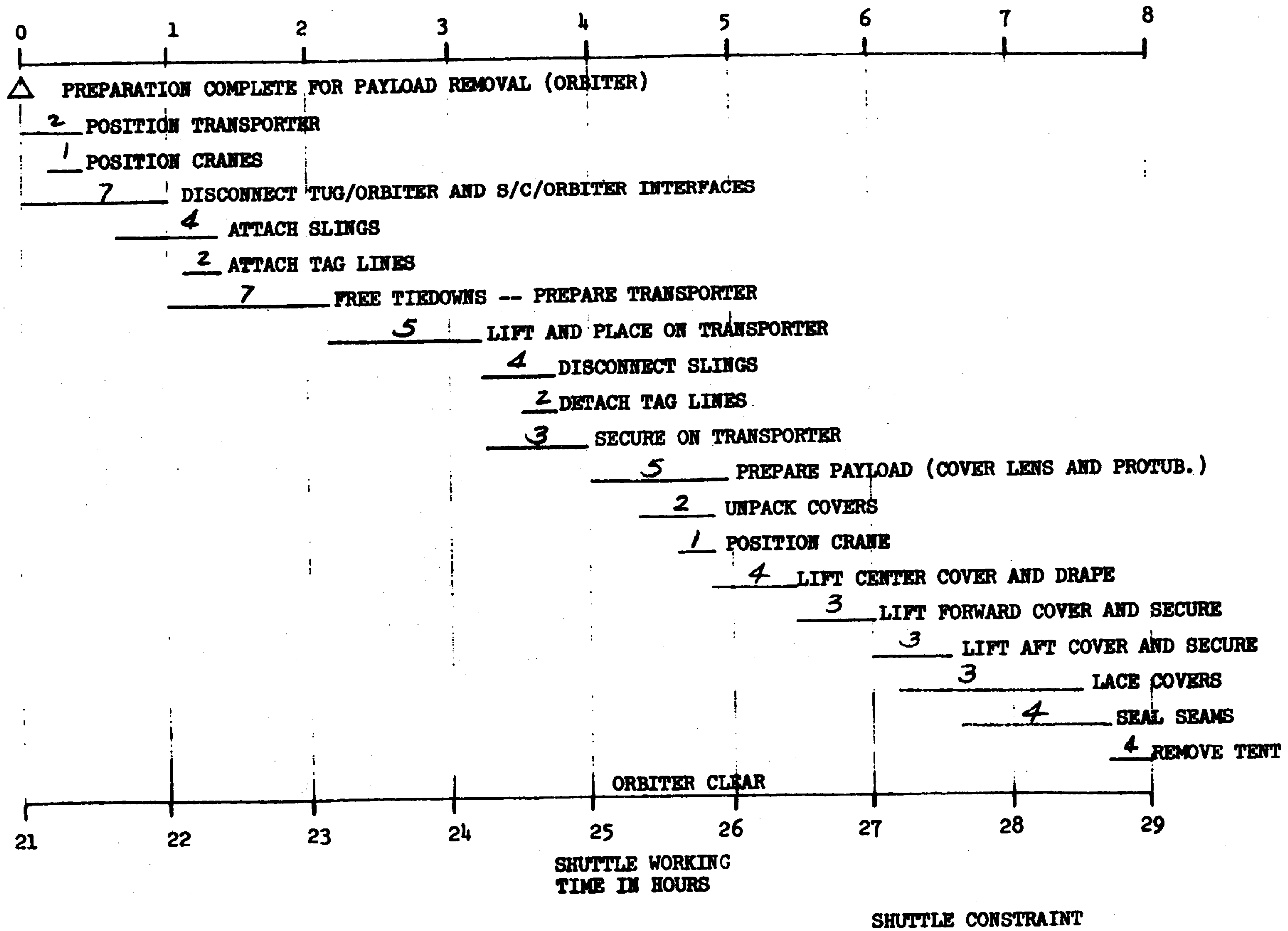
OPTION NUMBER 3F KSC	FUNCTION TITLE TUG GROUND SAFING AT SAFING AREA	FLOW BLOCK NO. 3.1.1



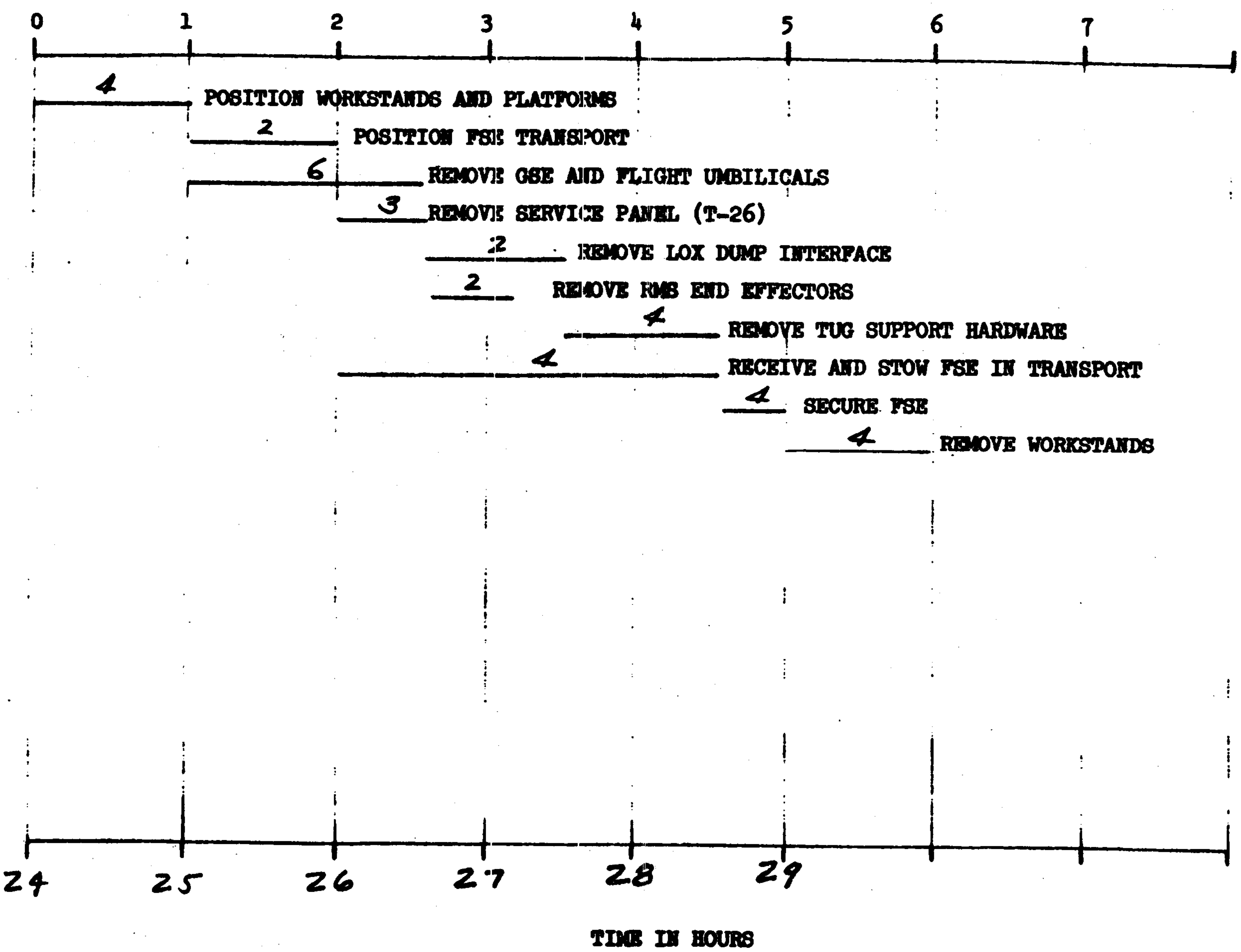
NOTE: NO RESIDUAL LIQUIDS

SHUTTLE CONSTRAINTS

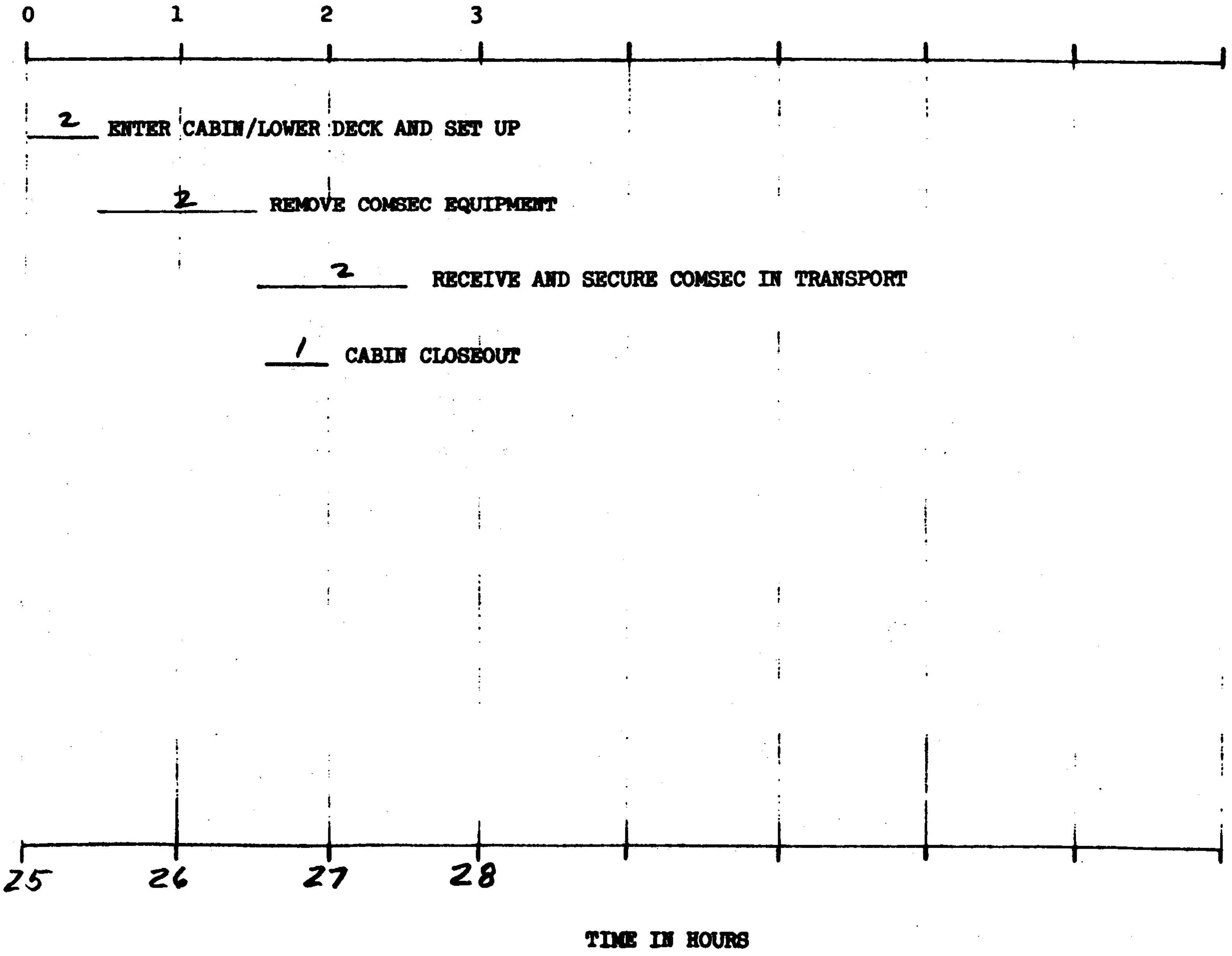
OPTION NUMBER 3F KSC	FUNCTION TITLE RECOVER TUG AND S/C AT MCF	FLOW BLOCK NO. 3.2.5



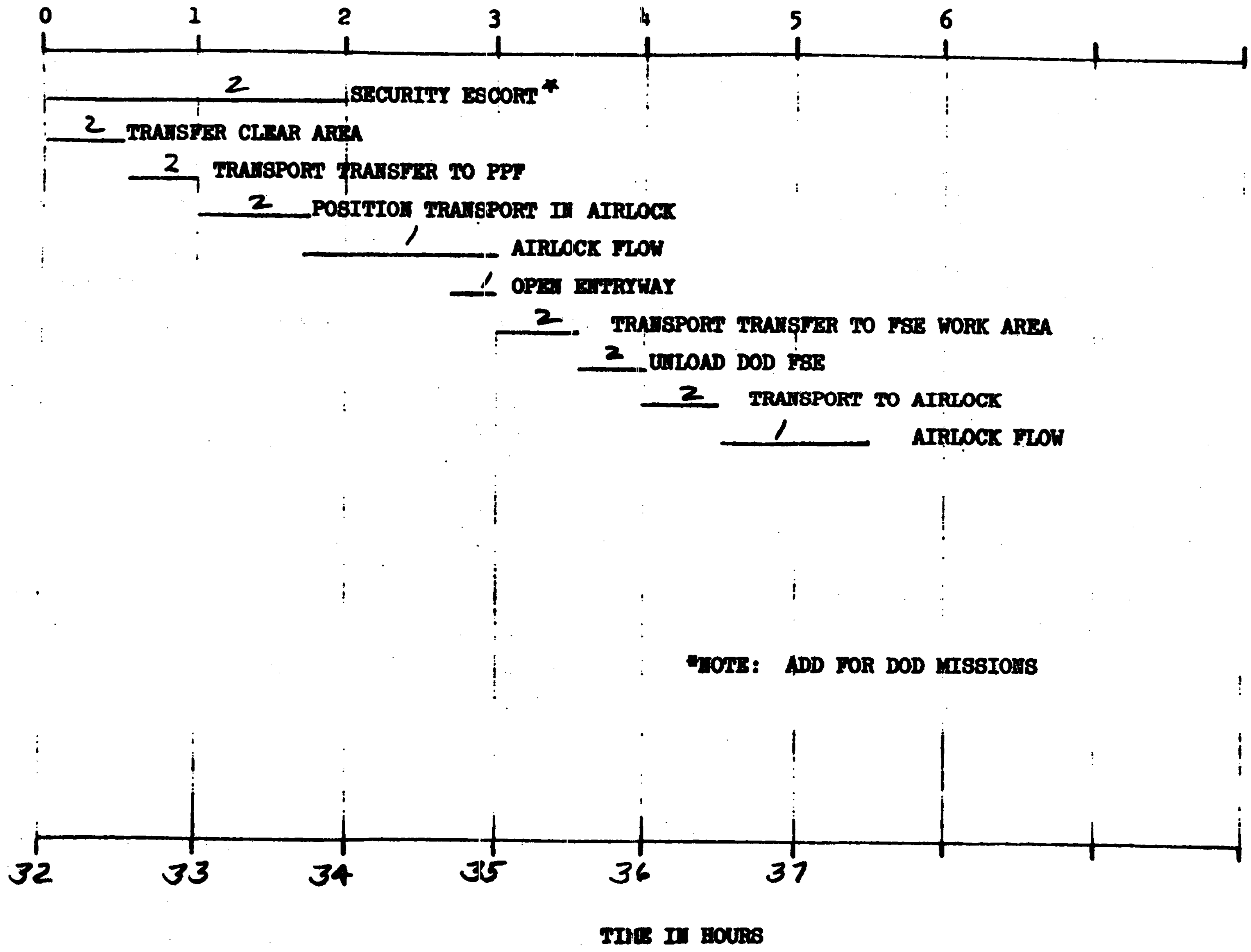
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F KSC ALL	RECOVER FSE (PAYLOAD BAY) EQUIPMENT	3.2.7



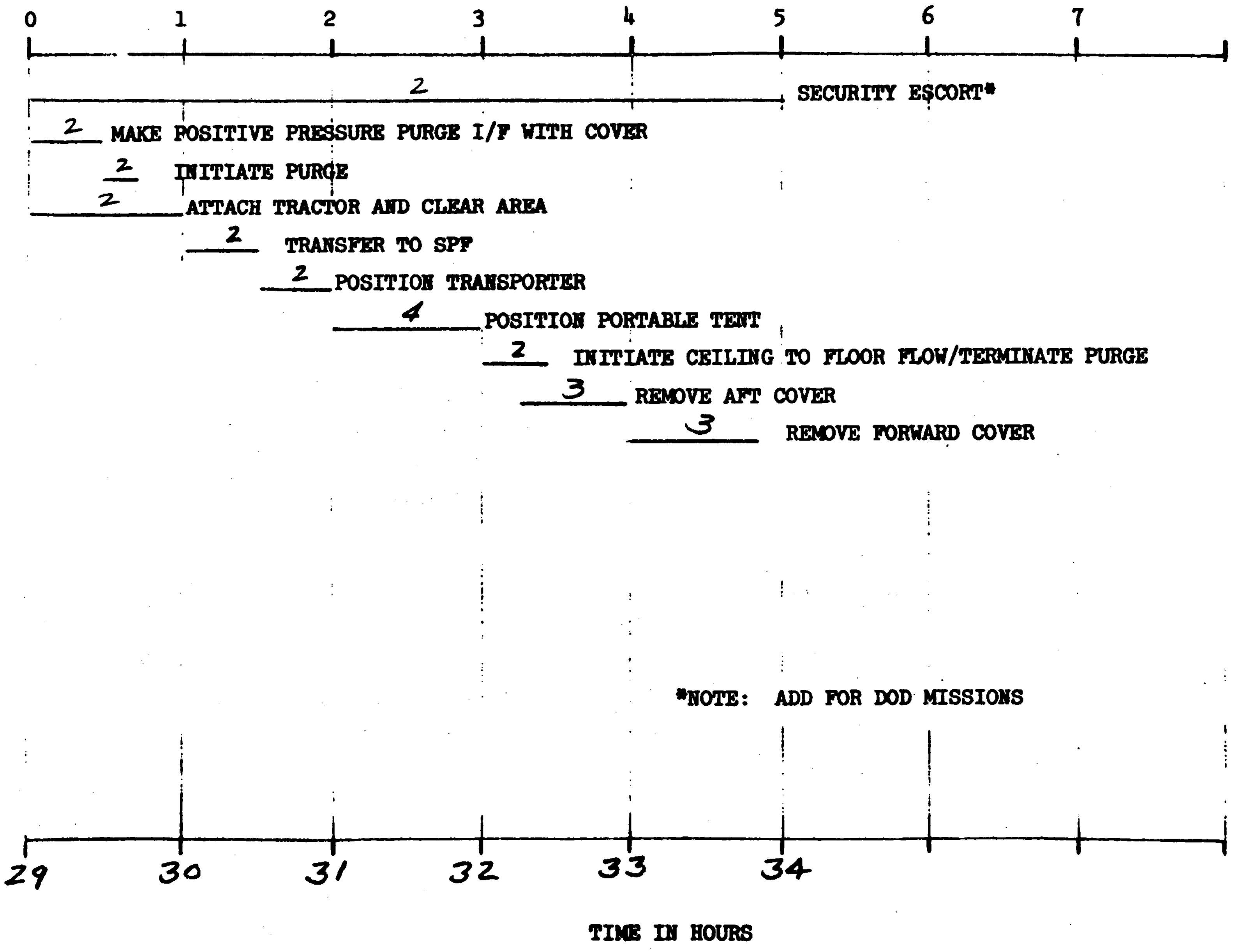
OPTION NUMBER 3F KSC ALL DOD	FUNCTION TITLE RECOVER FSE (CABIN) EQUIPMENT (COMSEC)	FLOW BLOCK NO. 3.2.6.b



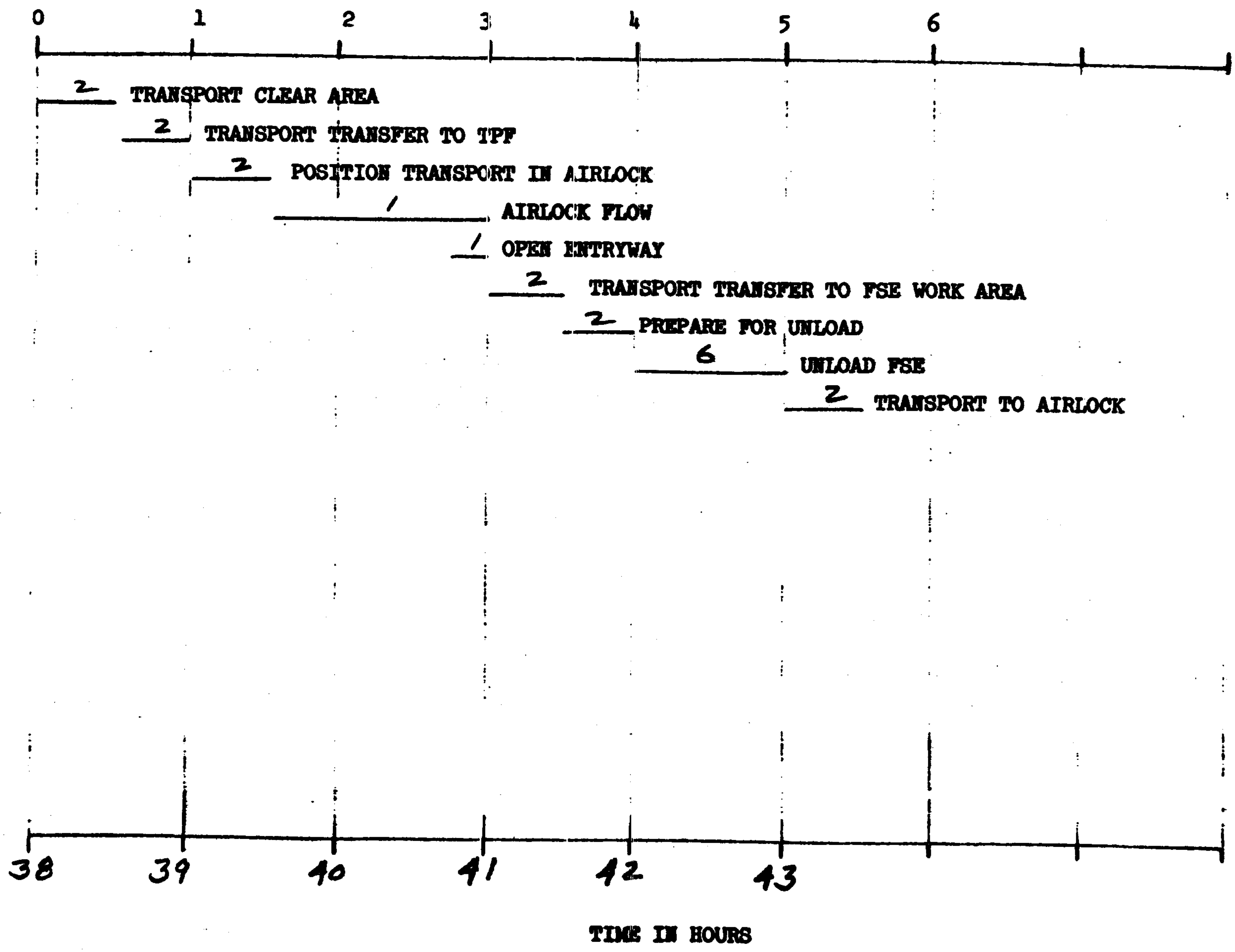
OPTION NUMBER 3F KSC	FUNCTION TITLE TRANSFER FSE TO PPF	FLOW BLOCK NO. 3.2.8



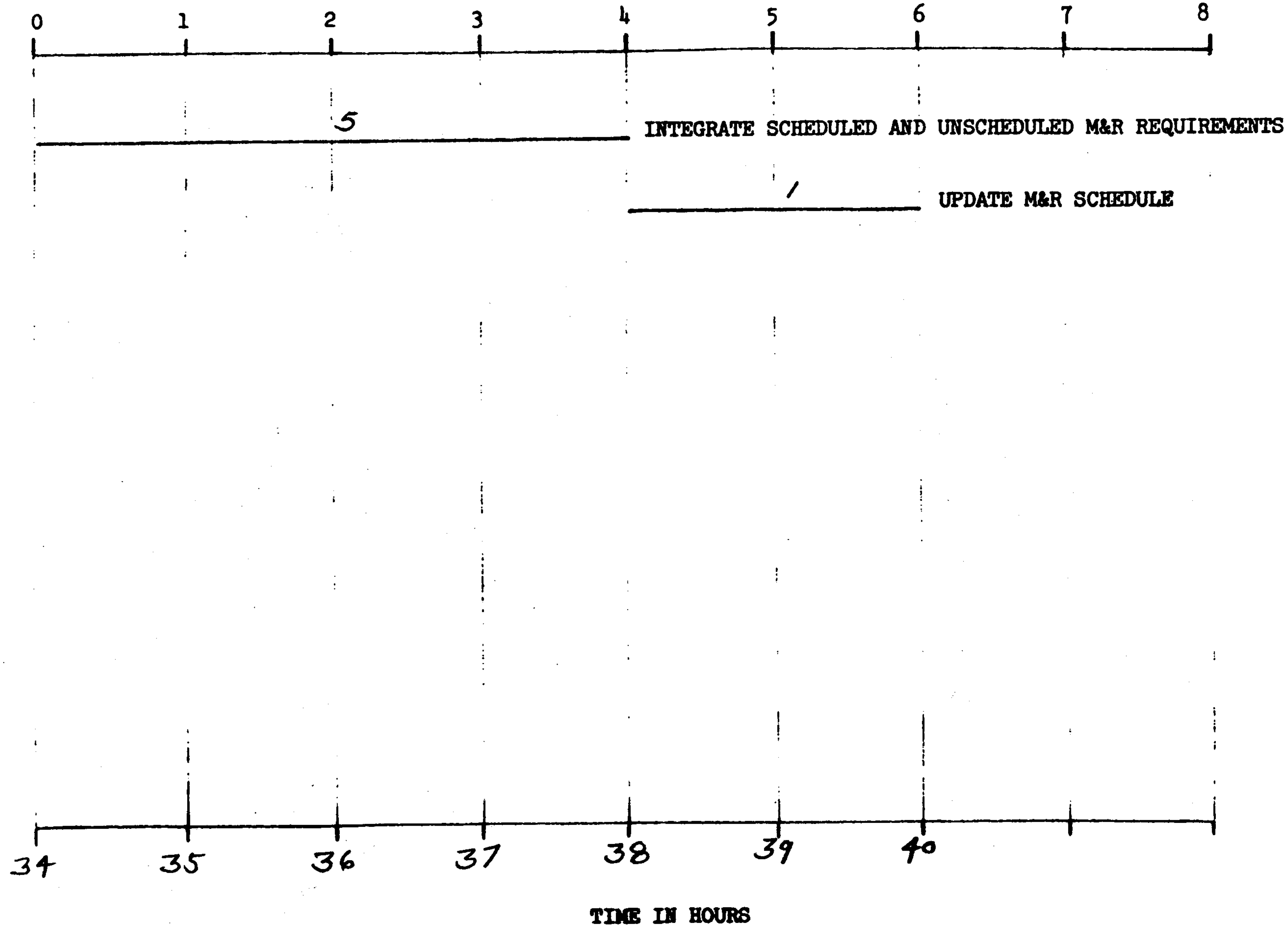
OPTION NUMBER	3F KSC	FUNCTION TITLE	TRANSFER TUG AND S/C TO SPF	FLOW BLOCK NO.	3.1.4



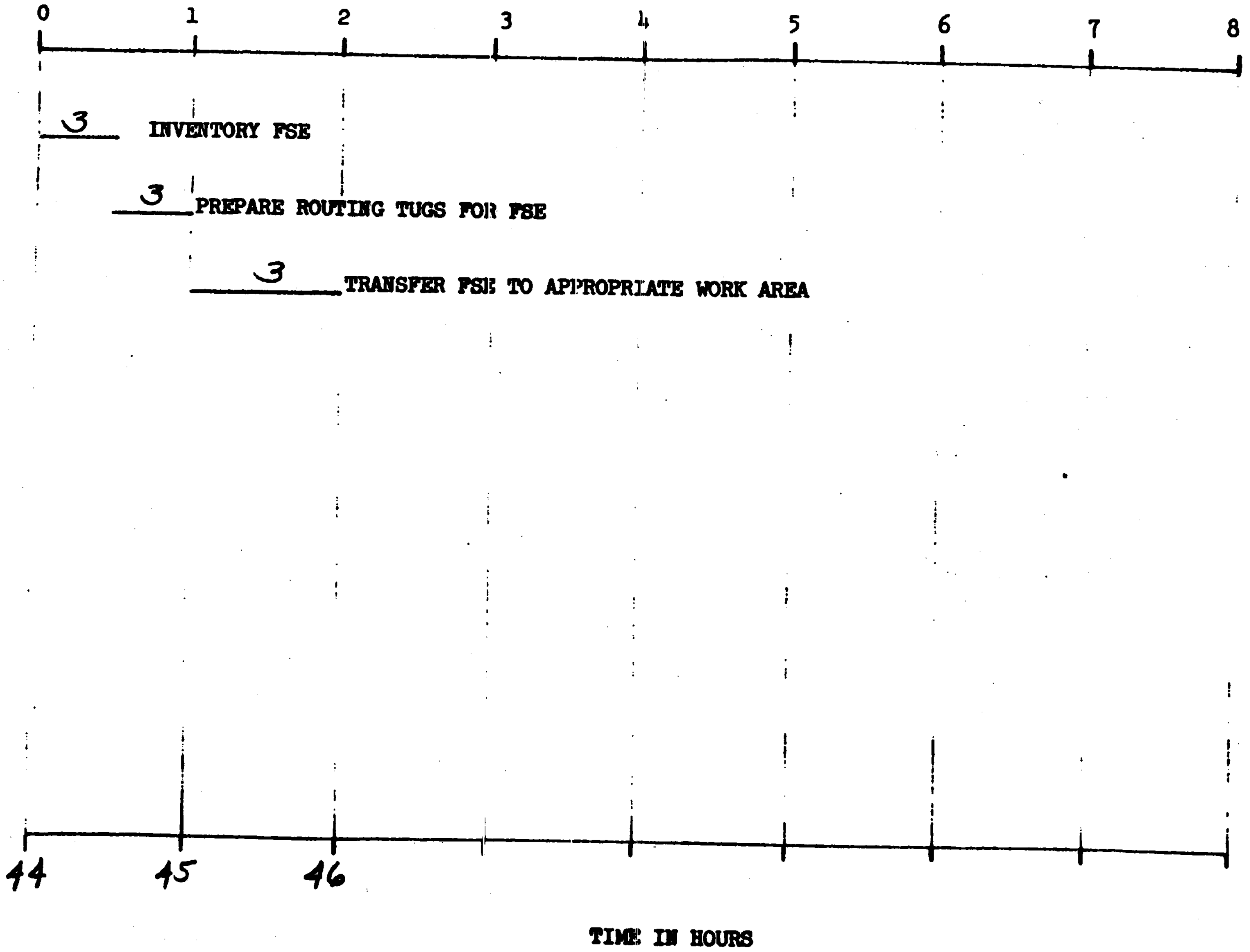
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F KSC	TRANSFER FSE TO TPF	3.2.9



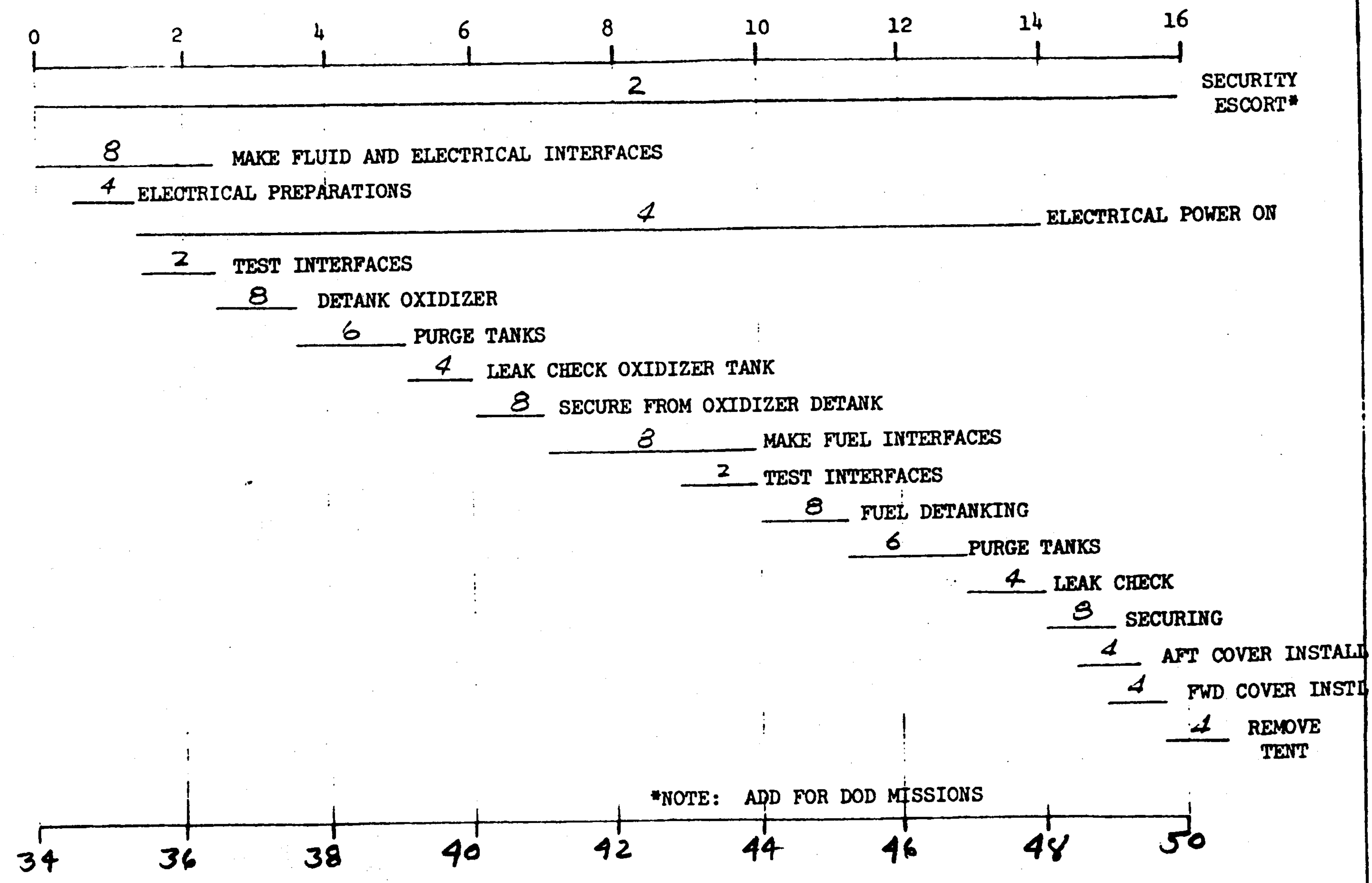
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F KSC	UPDATE M&R SCHEDULE	1.1.3



OPTION NUMBER 3F KSC	FUNCTION TITLE RECEIVE FSE AT TPF/PPF	FLOW BLOCK NO. 1.1.15

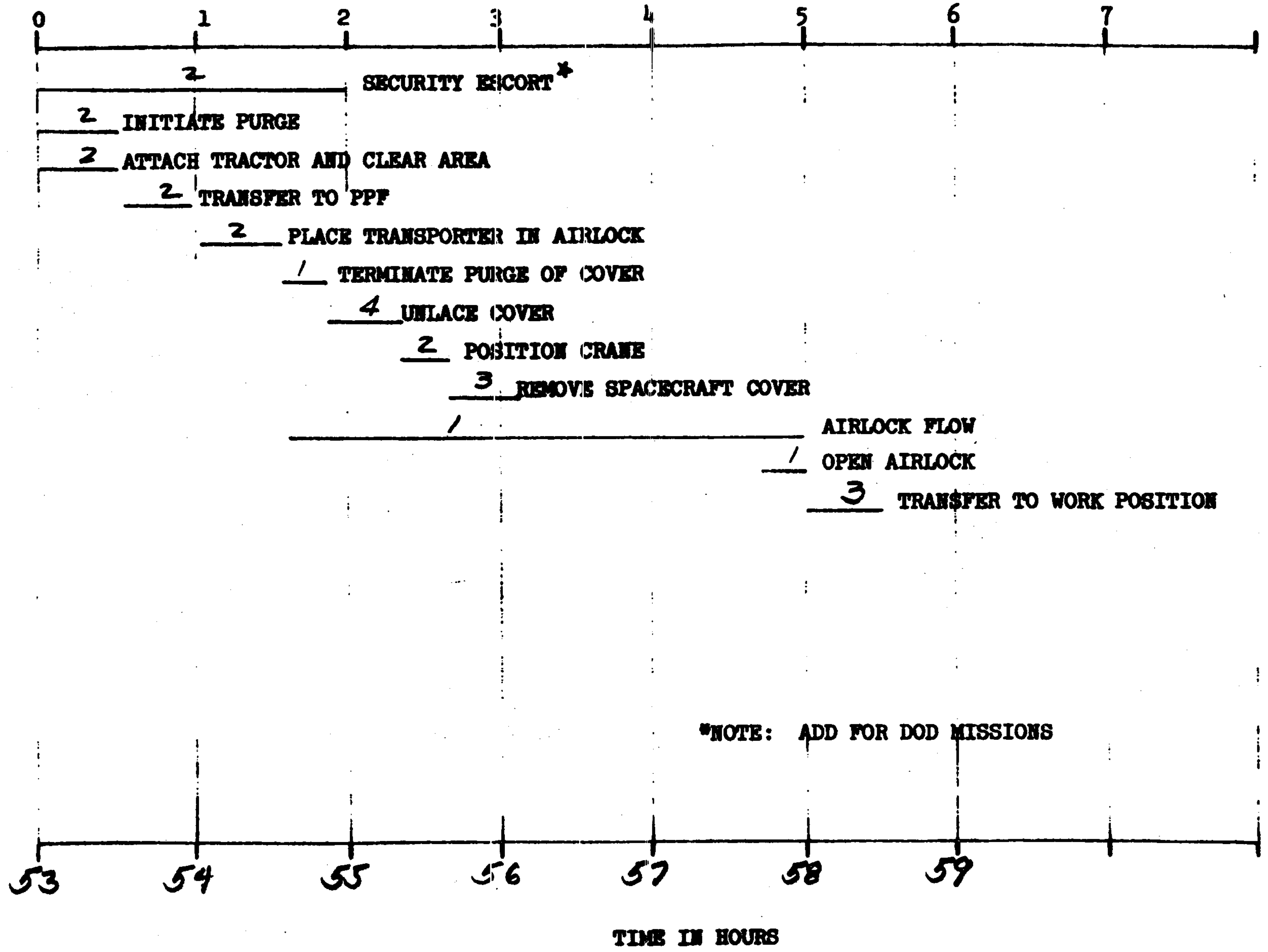


OPTION NUMBER 3F KSC	FUNCTION TITLE TUG SAFING	FLOW BLOCK NO. 3.1.7

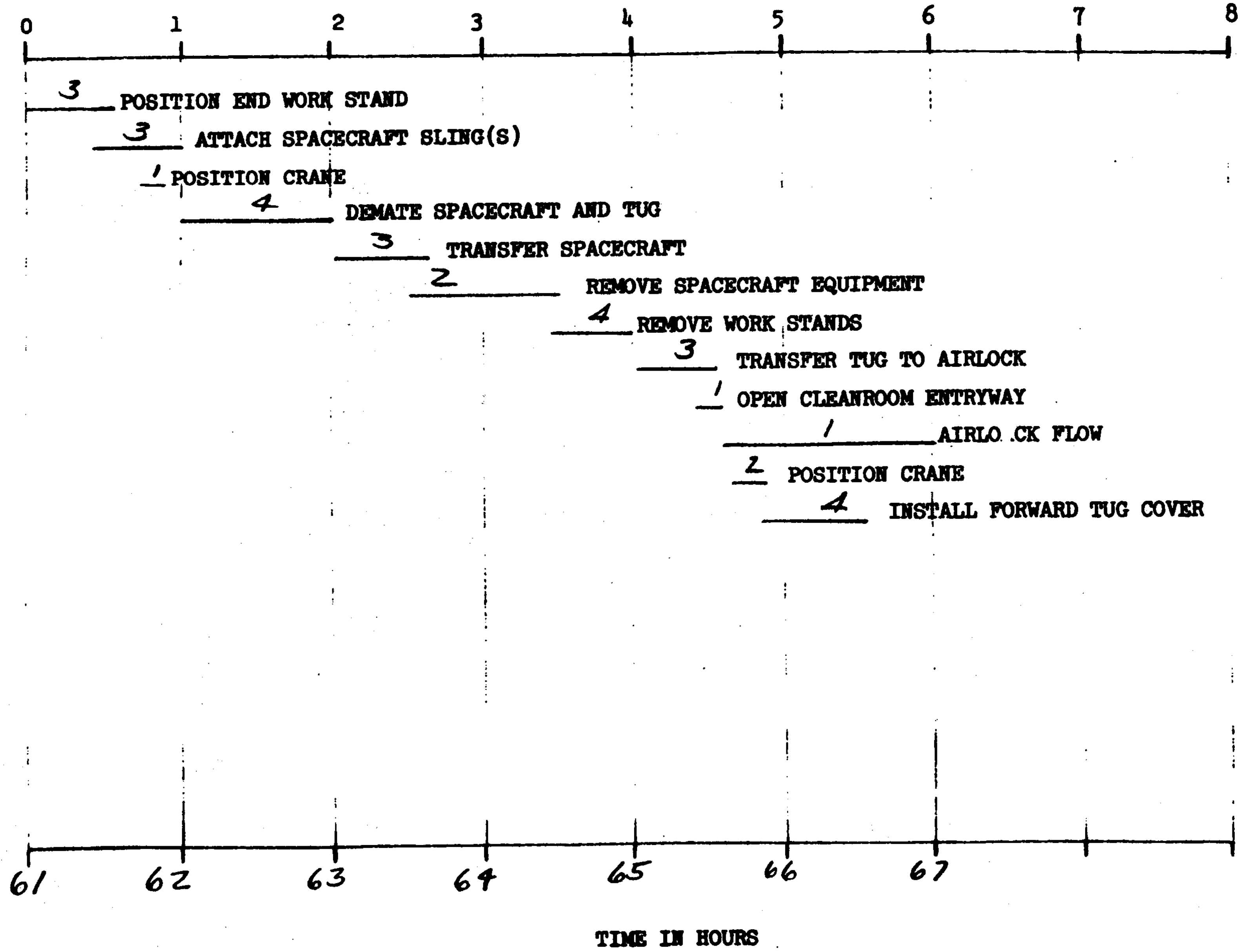


NOTES: BIPROPELLANT AT SPF

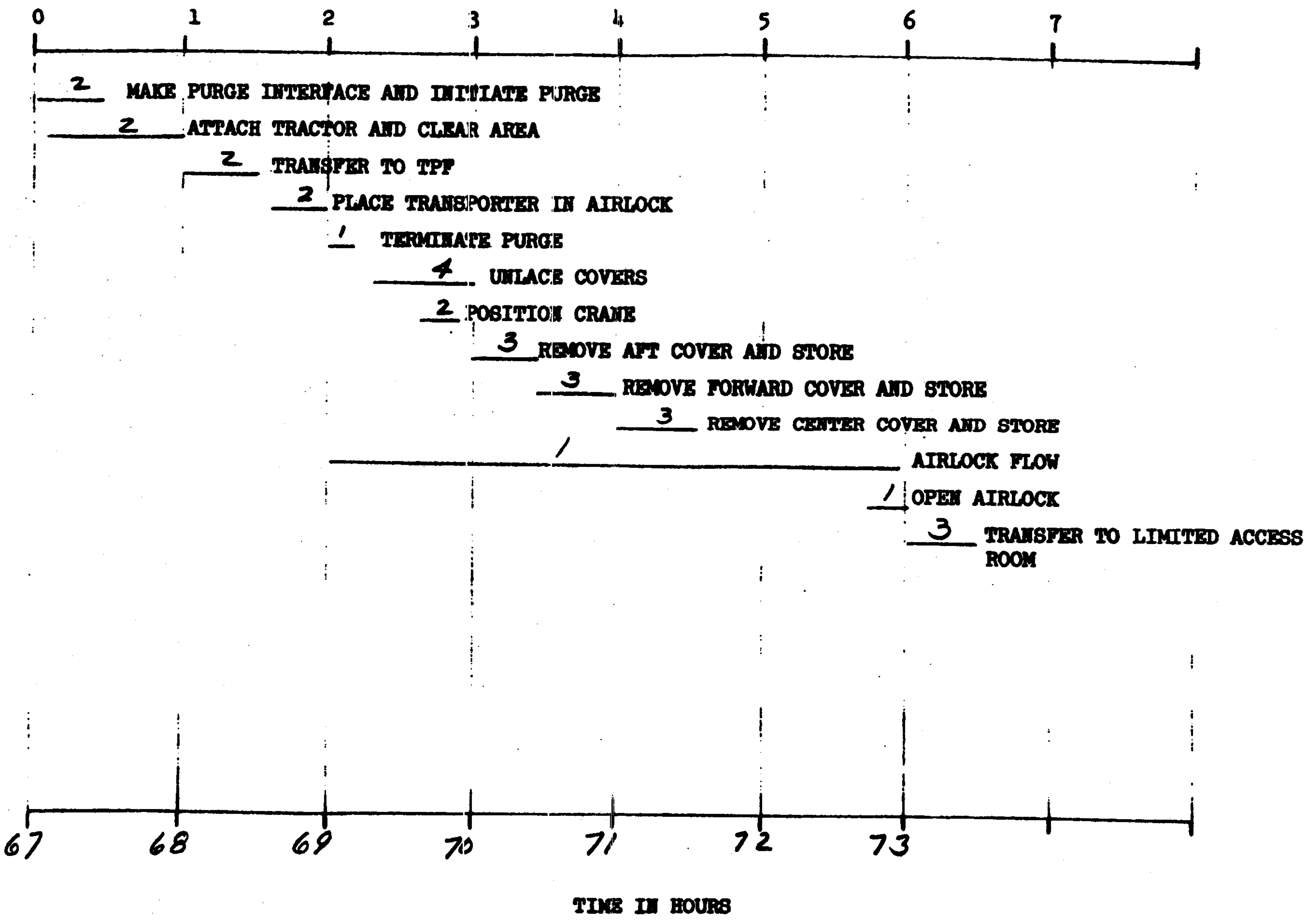
OPTION NUMBER 3F KSC	FUNCTION TITLE TRANSFER TUG AND S/C TO PPF	FLOW BLOCK NO. 3.3.1



OPTION NUMBER 3F KSC	FUNCTION TITLE DEMATE TUG AND SPACECRAFT	FLOW BLOCK NO. 3.3.7



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F KSC	TRANSFER TUG TO TPF	3.3.3



OPTION NUMBER 3F KSC	FUNCTION TITLE RECEIVE TUG AT TPF/PPF	FLOW BLOCK NO. 1.1.4

0 1 2 3 4 5 6 7 8

3 POSITION TUG (ON TRANSPORTER) AND ESTABLISH AND VERIFY ELECTRICAL GROUND

3 REMOVE PROTECTIVE COVERS

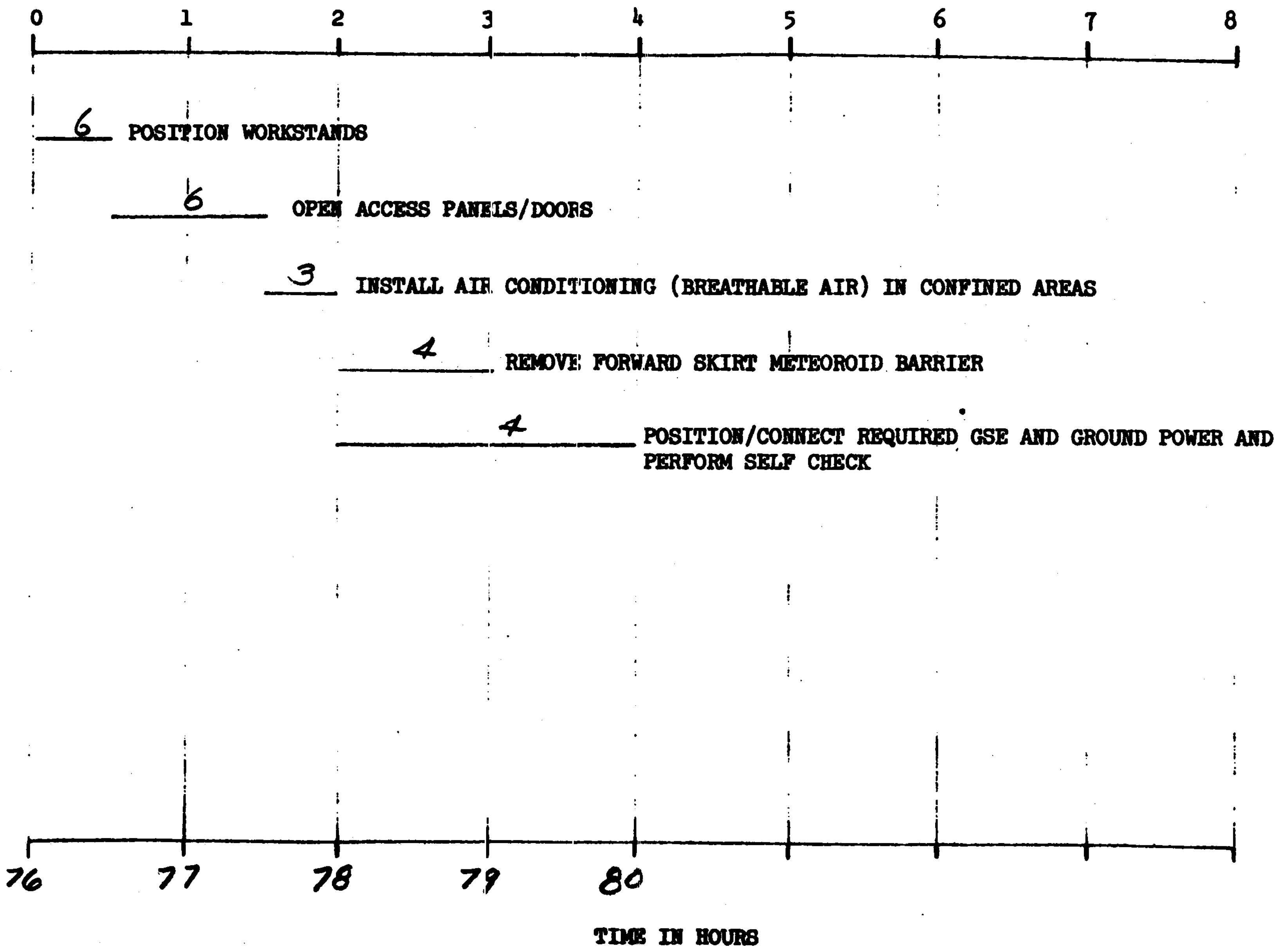
2 PERFORM SAFETY CHECK

59 60 61

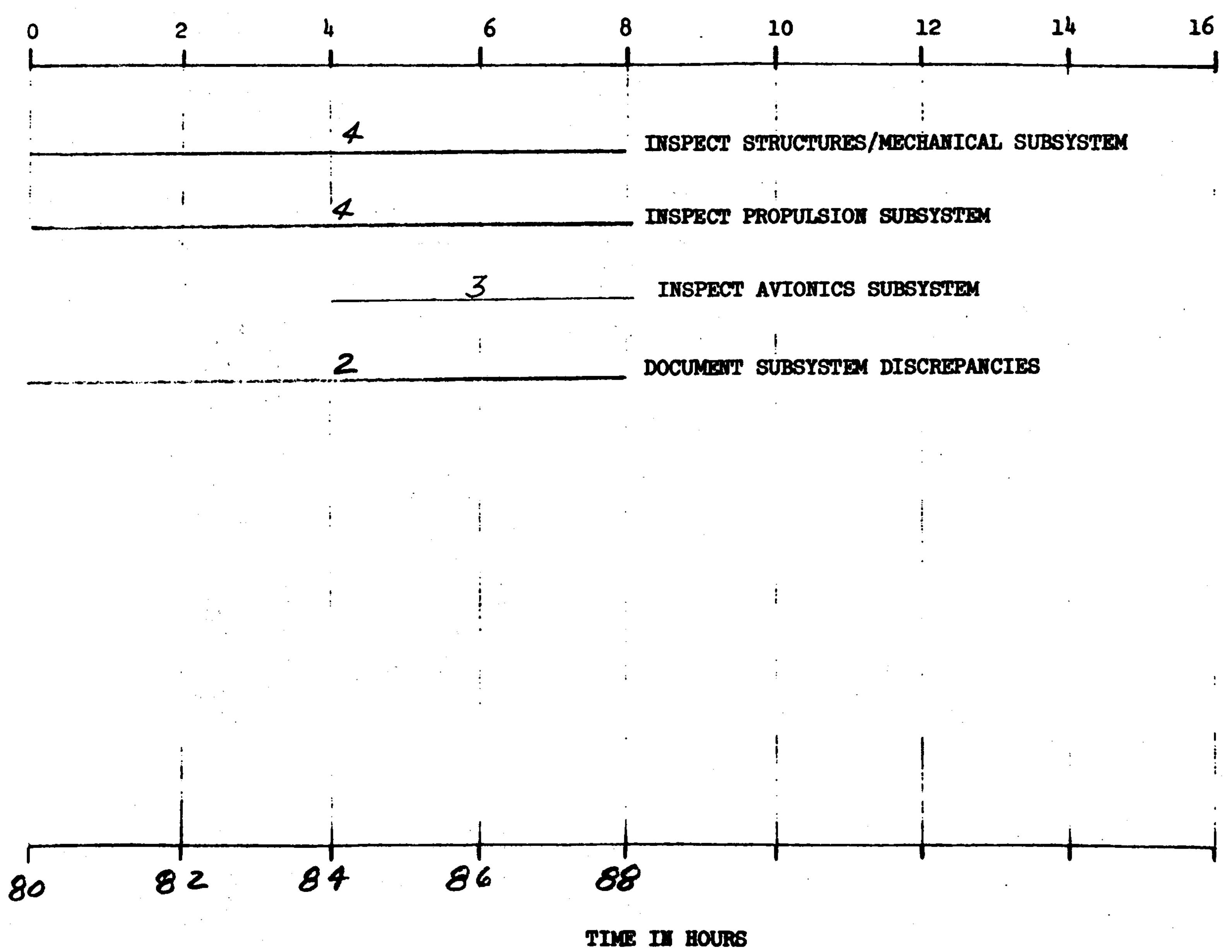
74 75 76

TIME IN HOURS

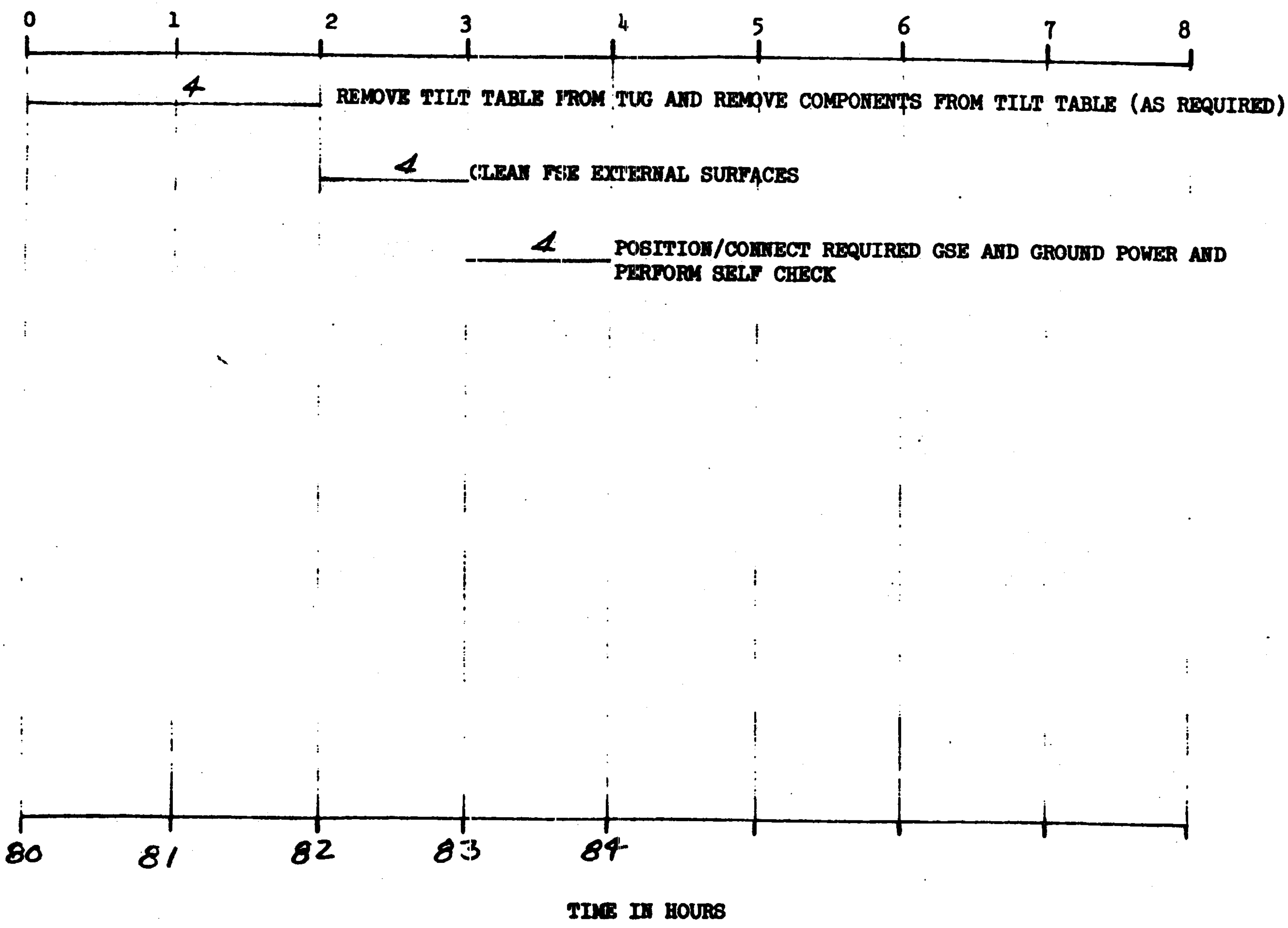
OPTION NUMBER	3F KSC	FUNCTION TITLE	PREPARE FOR INSPECTION AND C/O	FLOW BLOCK NO.	1.1.5



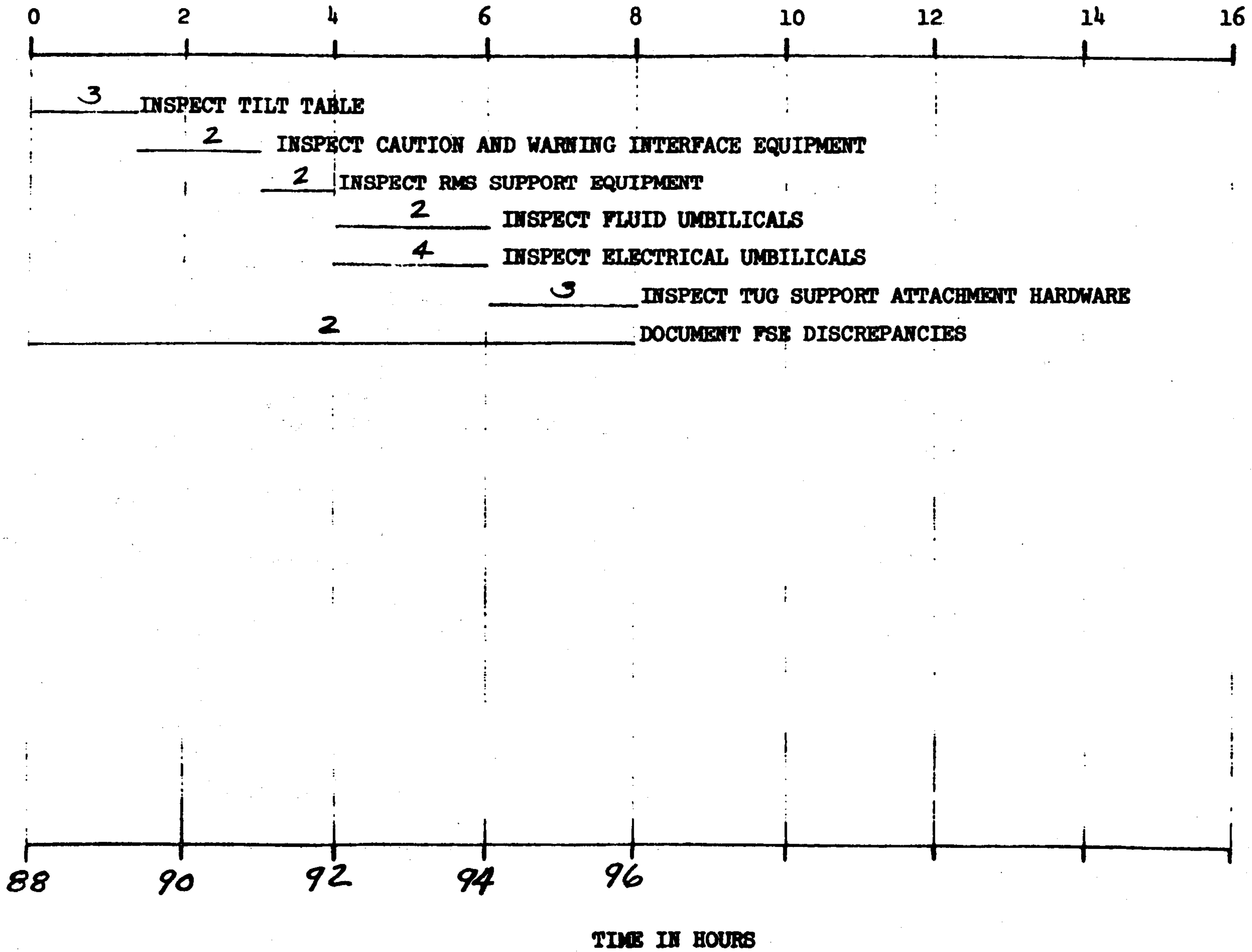
OPTION NUMBER 3F KSC	FUNCTION TITLE PERFORM POST FLIGHT RECEIVING INSPECTION	FLOW BLOCK NO. 1.1.6



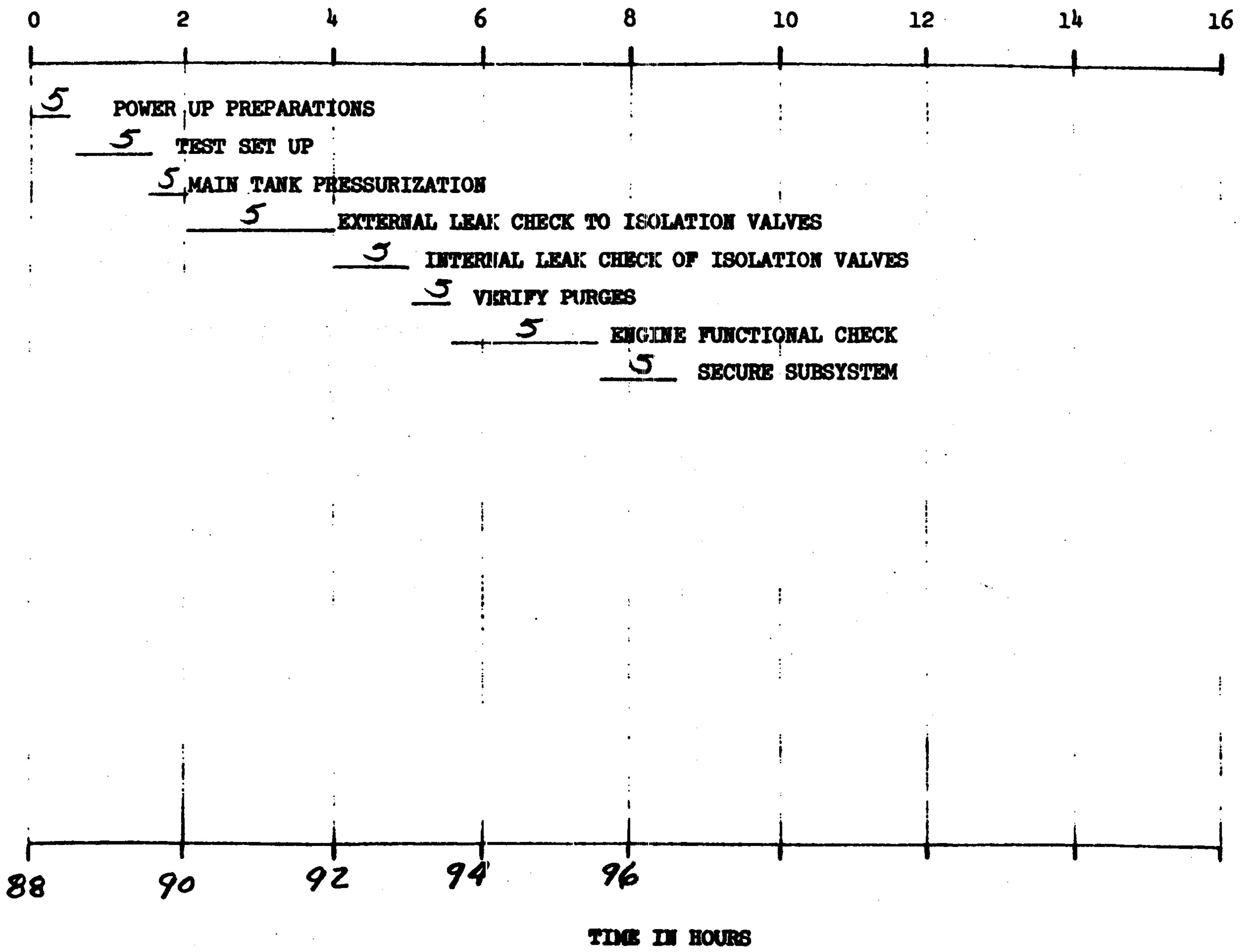
OPTION NUMBER 3F KSC	FUNCTION TITLE PREPARE FOR INSPECTION	FLOW BLOCK NO. 1.1.16



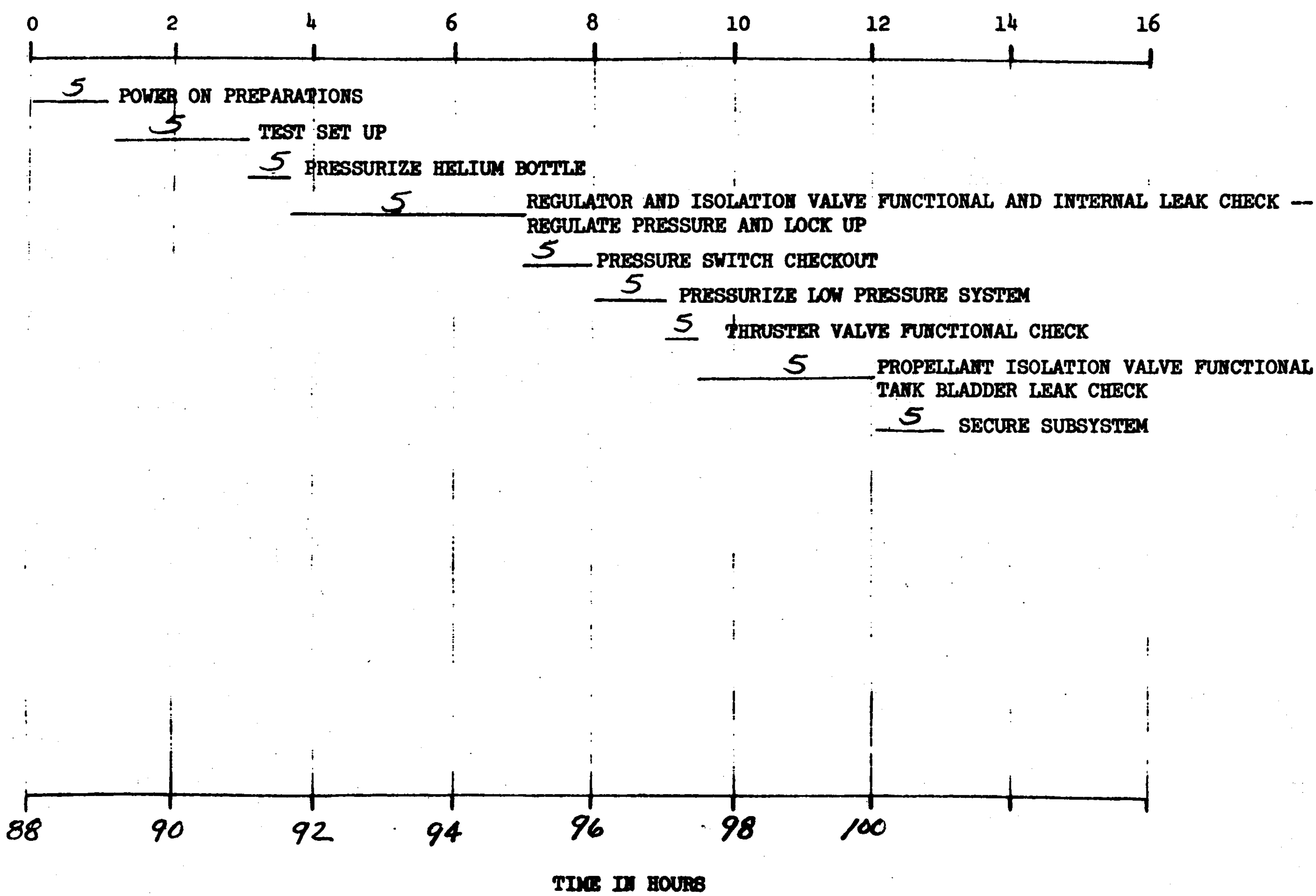
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F KSC	PERFORM FSE POST FLIGHT/RECEIVING INSPECTION	1.1.17



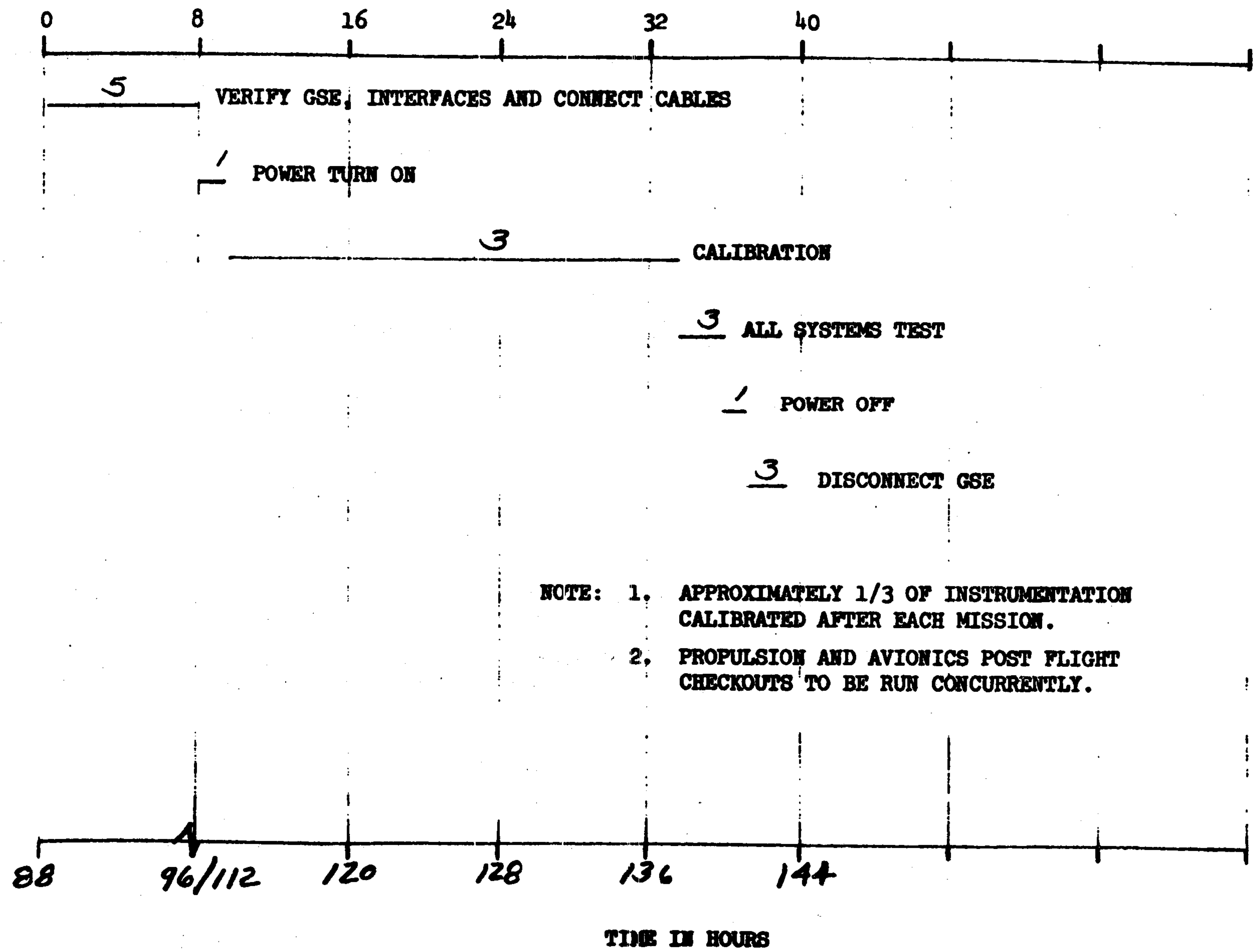
OPTION NUMBER 3F KSC	FUNCTION POST FLIGHT CHECKOUT - MAIN PROPULSION TITLE PRESSURIZATION - COLD HELIUM & GH_2 BLEED	FLOW BLOCK NO. 1.1.7.2



OPTION NUMBER	FUNCTION TITLE POST FLIGHT CHECKOUT - APS SUBSYSTEM - BIPROPELLANT	FLOW BLOCK NO. 1.1.7.7



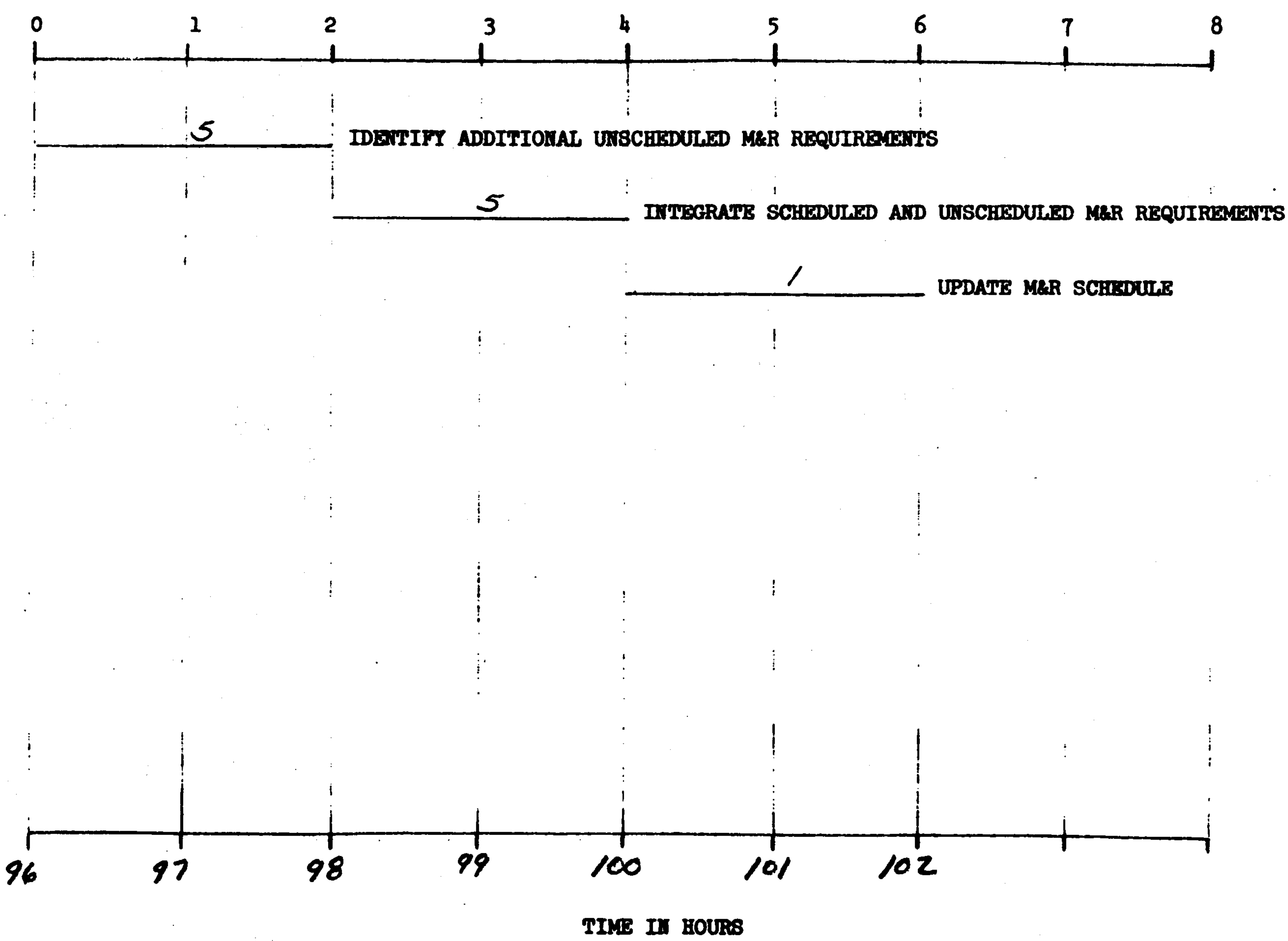
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F KSC	POST FLIGHT CHECKOUT - AVIONICS	1.1.7.9



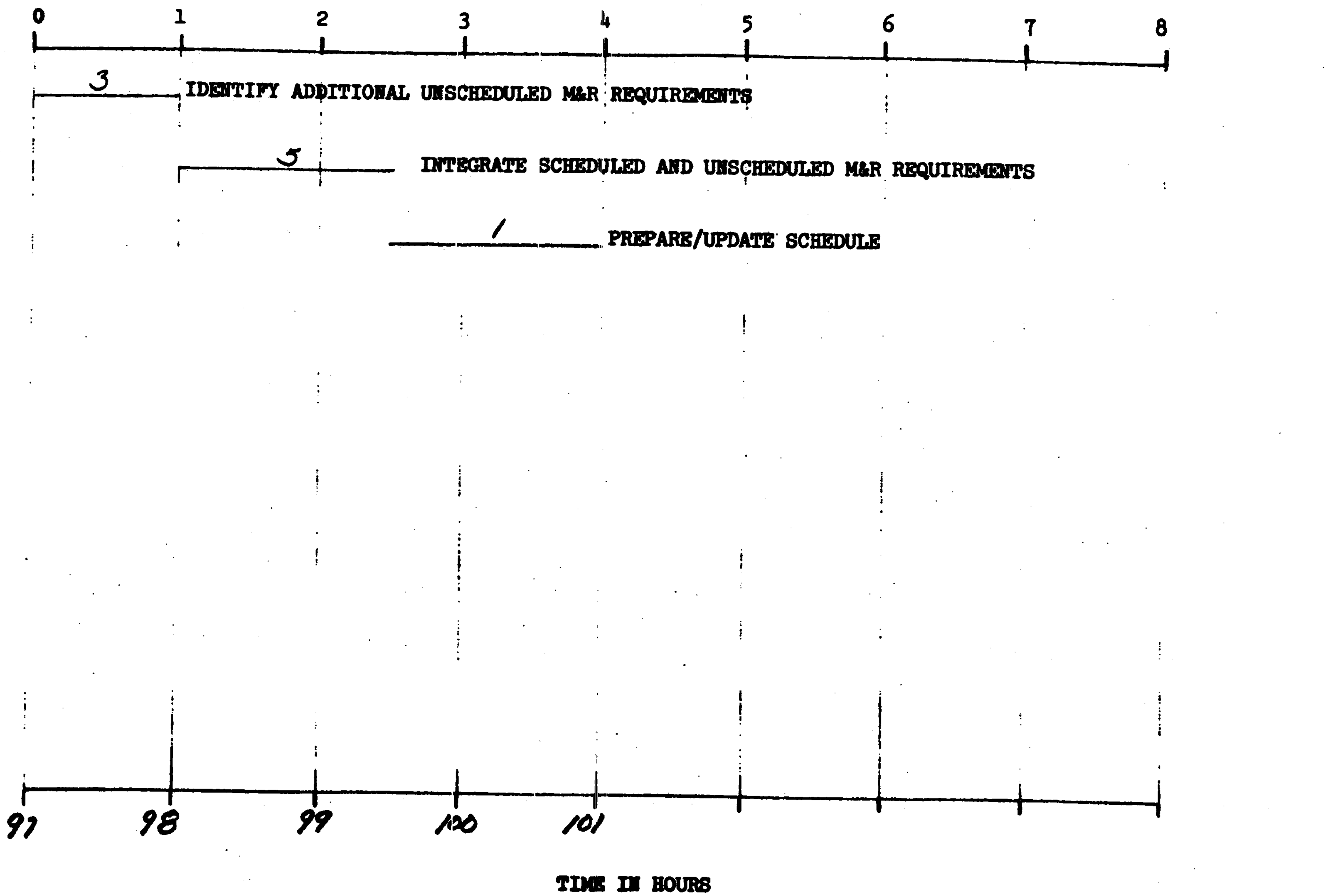
NOTE: 1. APPROXIMATELY 1/3 OF INSTRUMENTATION CALIBRATED AFTER EACH MISSION.

2. PROPULSION AND AVIONICS POST FLIGHT CHECKOUTS TO BE RUN CONCURRENTLY.

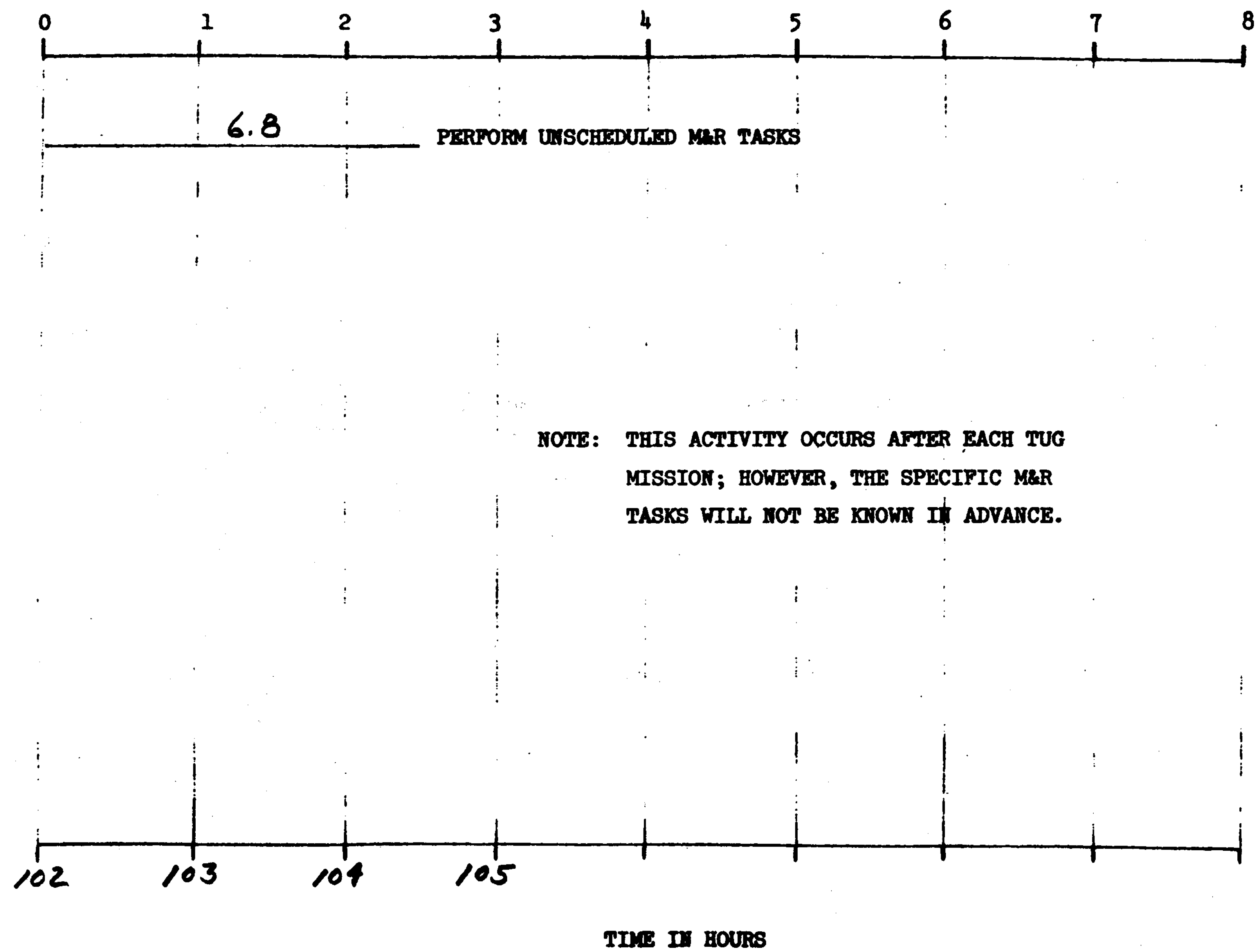
OPTION NUMBER	3F KSC	FUNCTION TITLE	PREPARE/UPDATE M&R SCHEDULE	FLOW BLOCK NO.	1.1.10



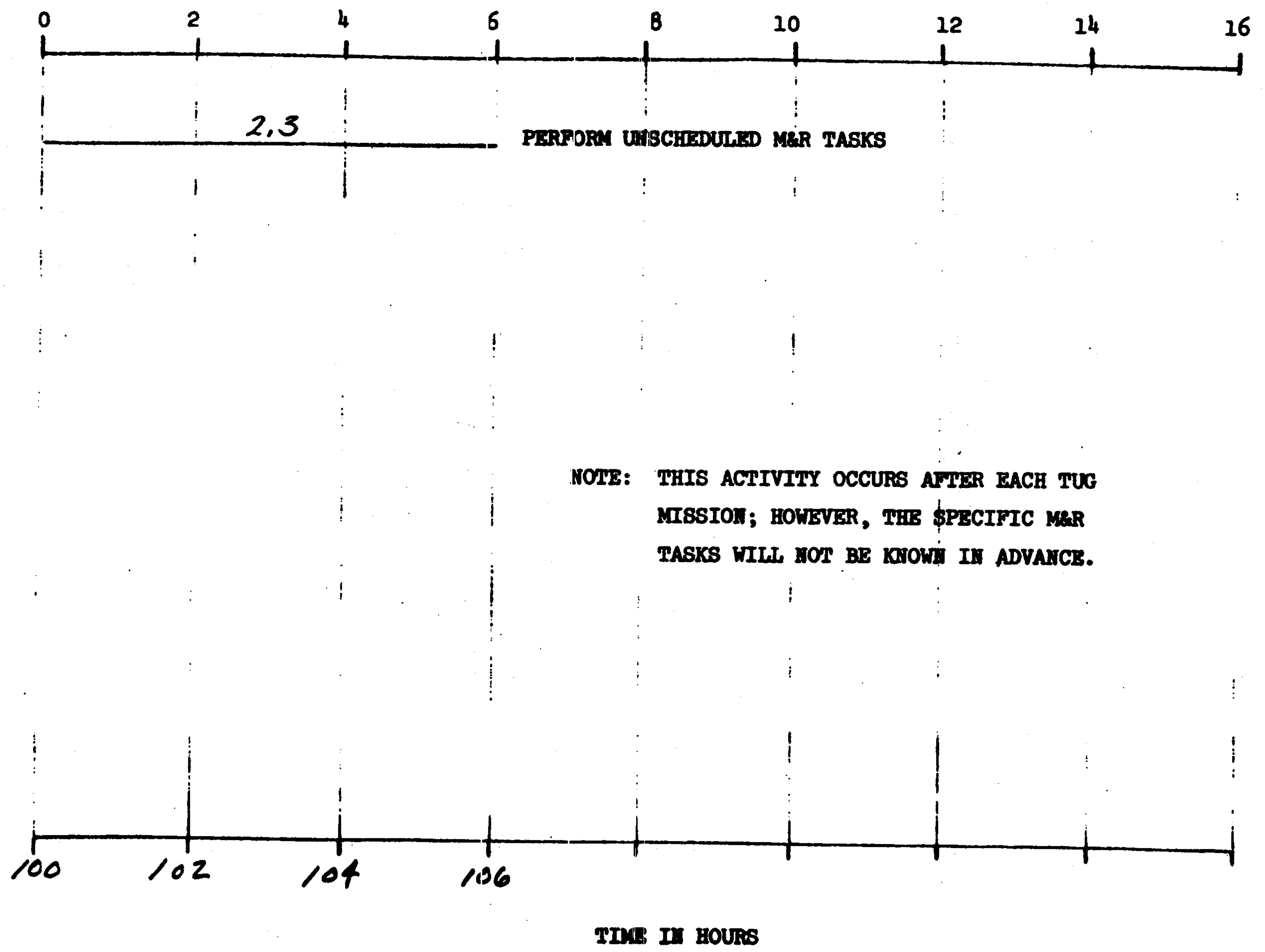
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F KSC	PREPARE/UPDATE M&R SCHEDULE	1.1.18



OPTION NUMBER 3F KSC	FUNCTION TITLE PERFORM STRUCTURAL/MECHANICAL M&R	FLOW BLOCK NO. 1.1.11

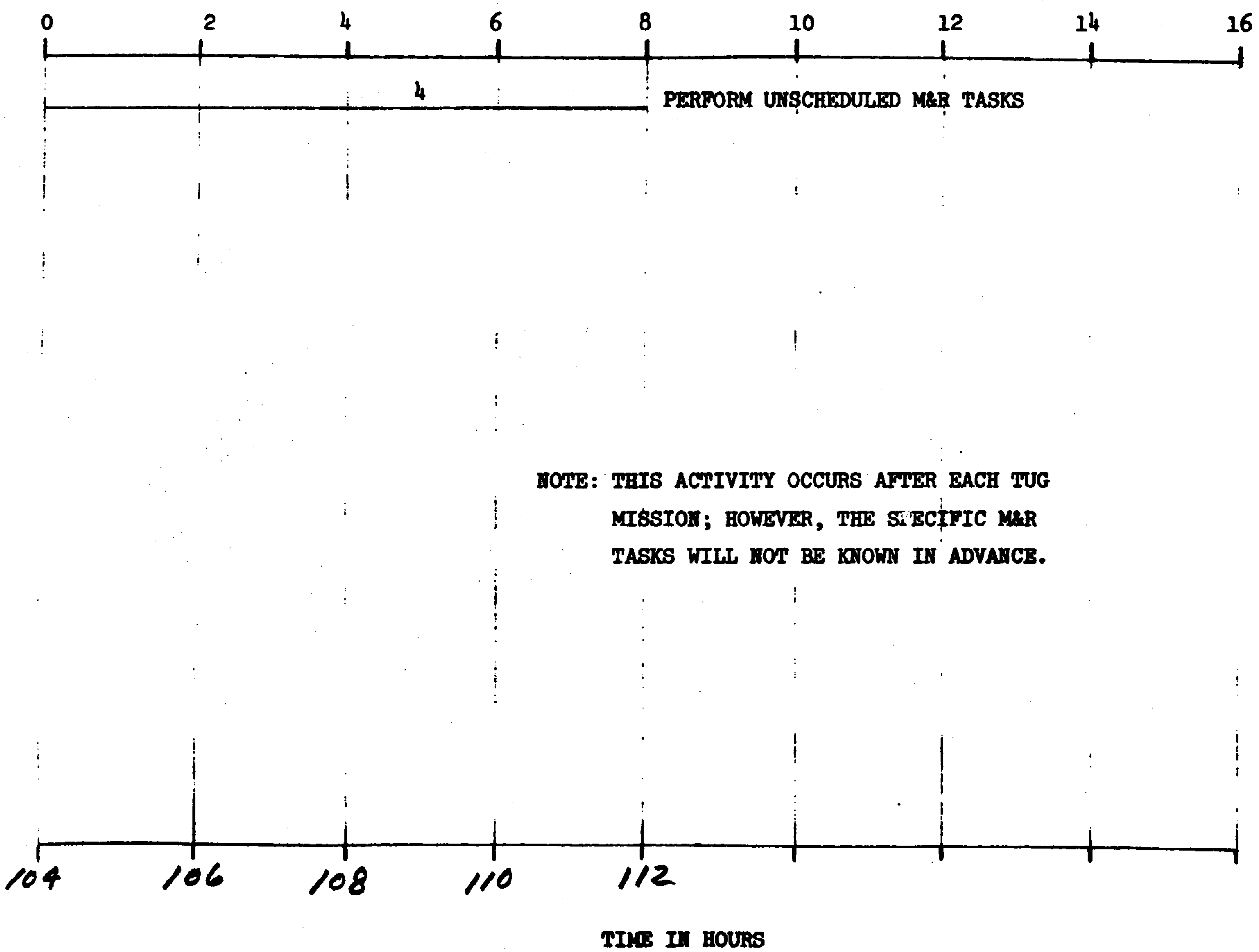


OPTION NUMBER 3F KSC	FUNCTION TITLE PERFORM PROPULSION M&R	FLOW BLOCK NO. 1.1.12

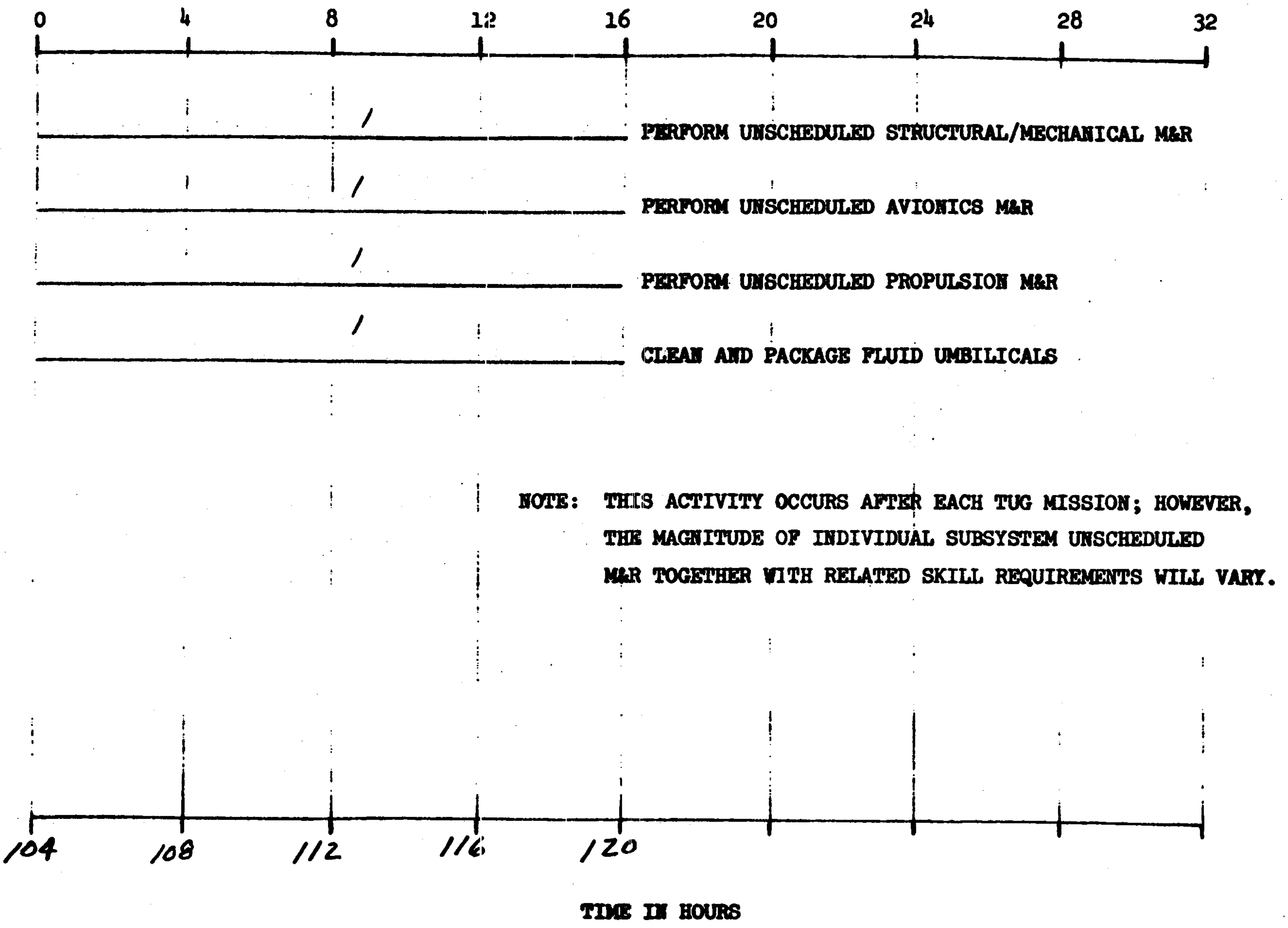


NOTE: THIS ACTIVITY OCCURS AFTER EACH TUG MISSION; HOWEVER, THE SPECIFIC M&R TASKS WILL NOT BE KNOWN IN ADVANCE.

OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F KSC	PERFORM AVIONICS M&R	1.1.13

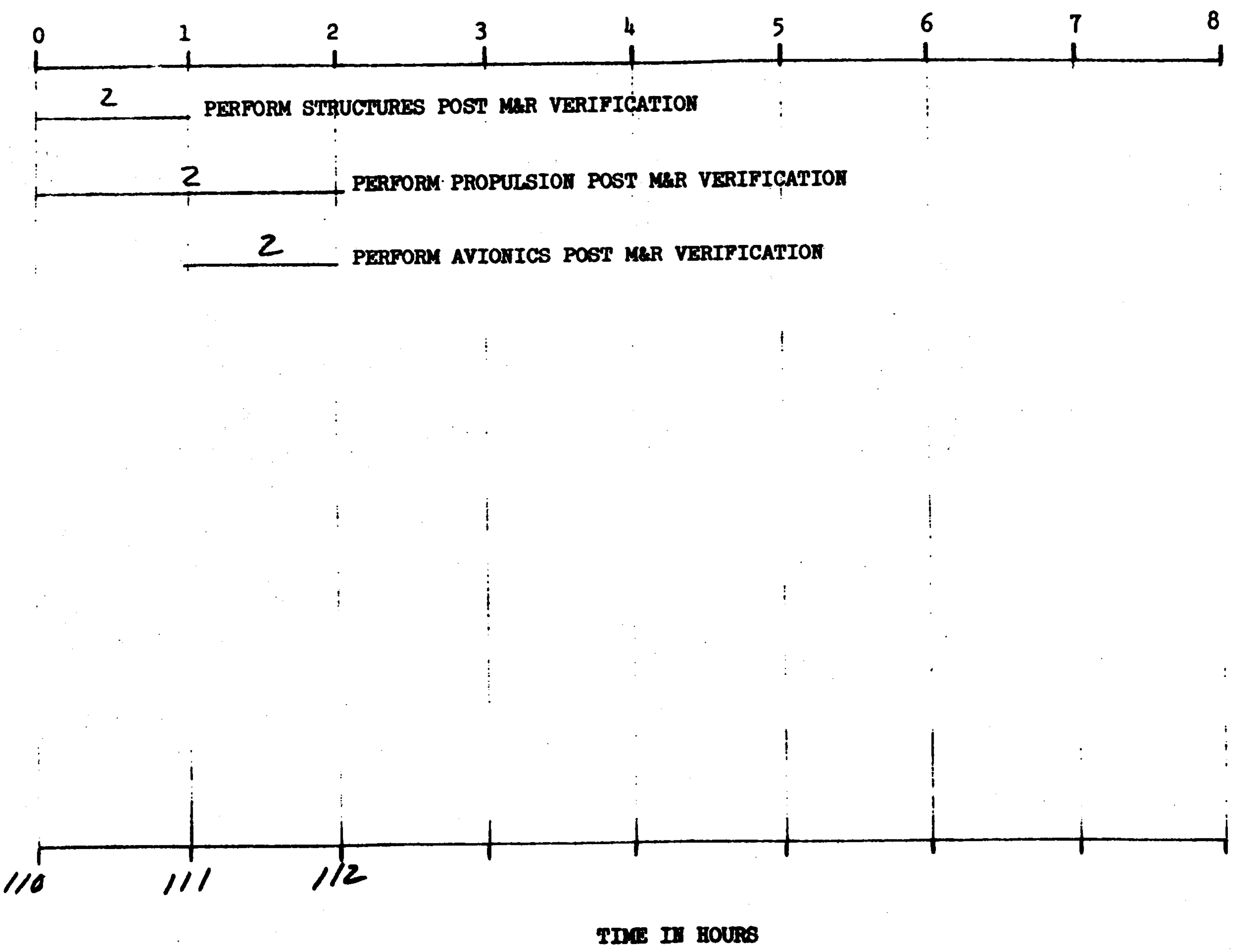


OPTION NUMBER 3F KSC	FUNCTION TITLE PERFORM FSE M&R	FLOW BLOCK NO. 1.1.19

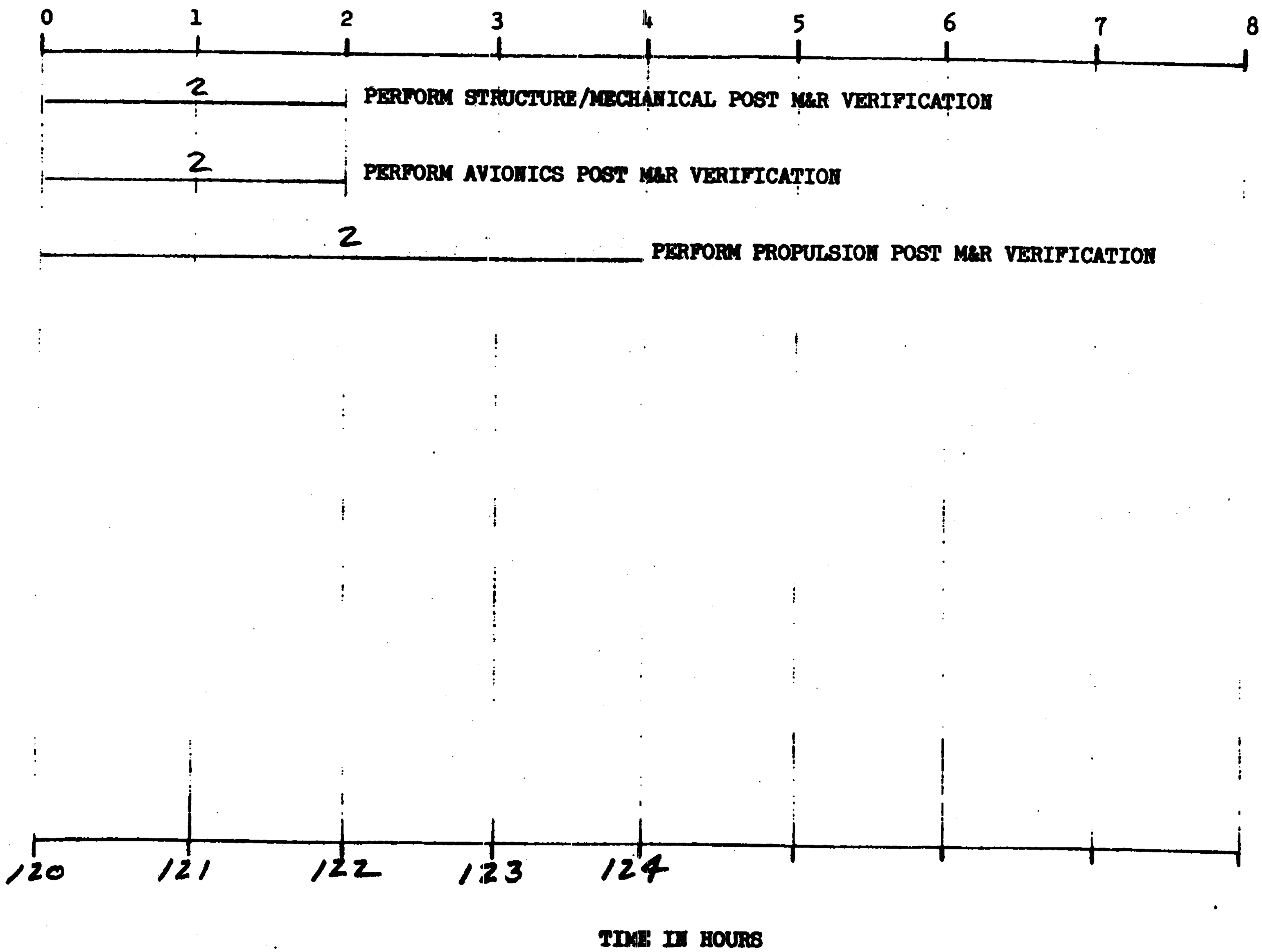


NOTE: THIS ACTIVITY OCCURS AFTER EACH TUG MISSION; HOWEVER, THE MAGNITUDE OF INDIVIDUAL SUBSYSTEM UNSCHEDULED M&R TOGETHER WITH RELATED SKILL REQUIREMENTS WILL VARY.

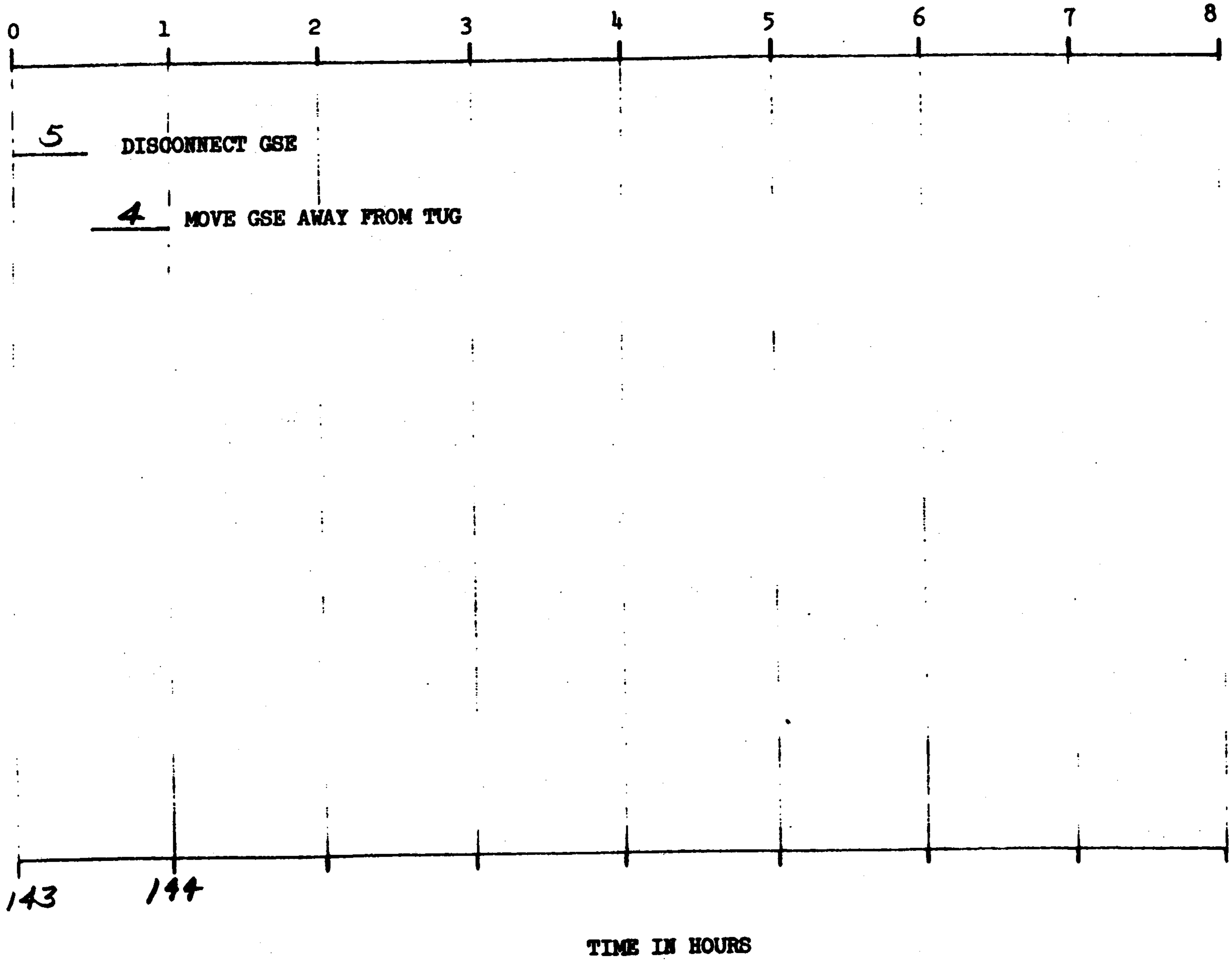
OPTION NUMBER 3F KSC	FUNCTION TITLE POST M&R VERIFICATION	FLOW BLOCK NO. 1.2.1



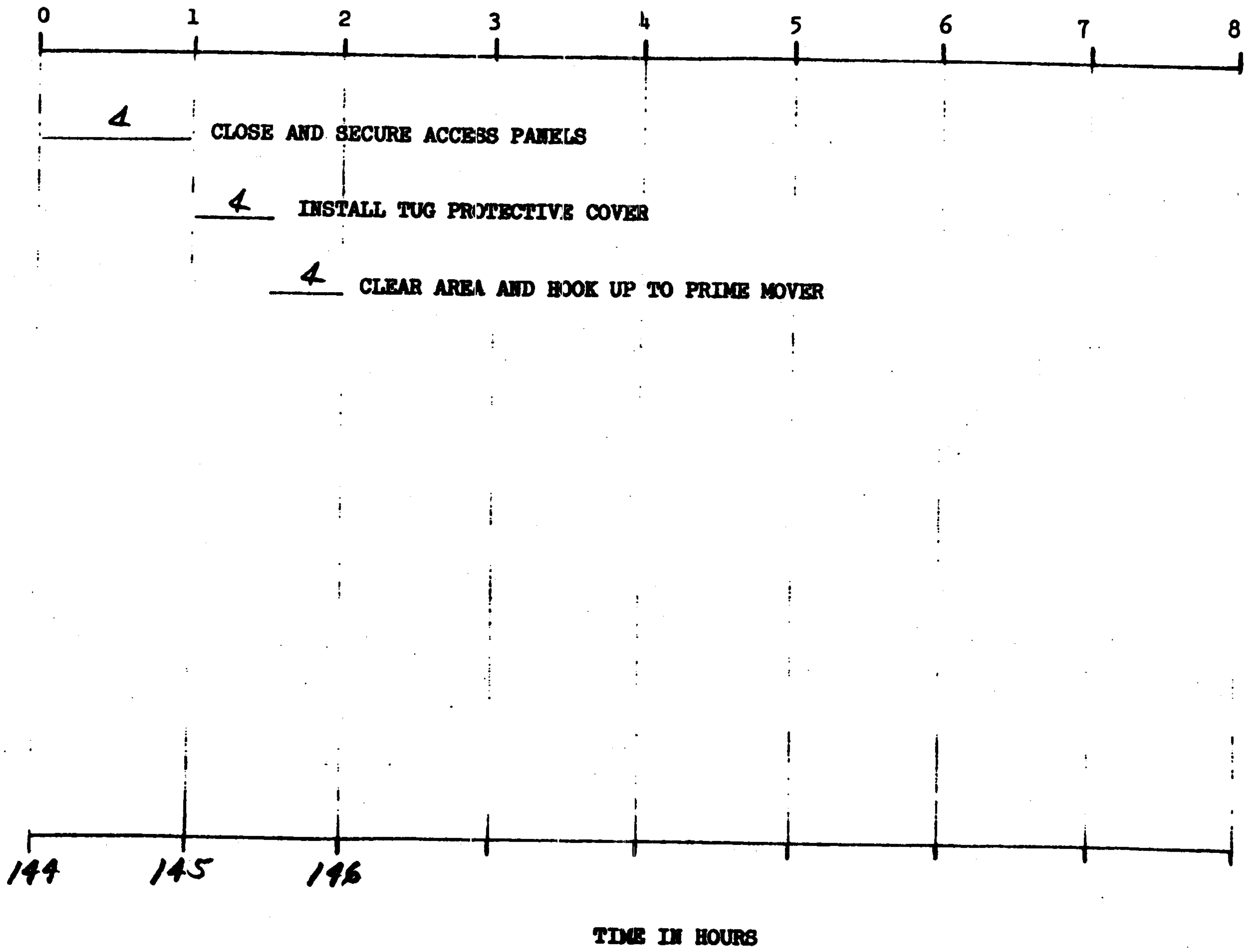
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F KSC	PERFORM POST M&R VERIFICATION - FSE	1.2.2



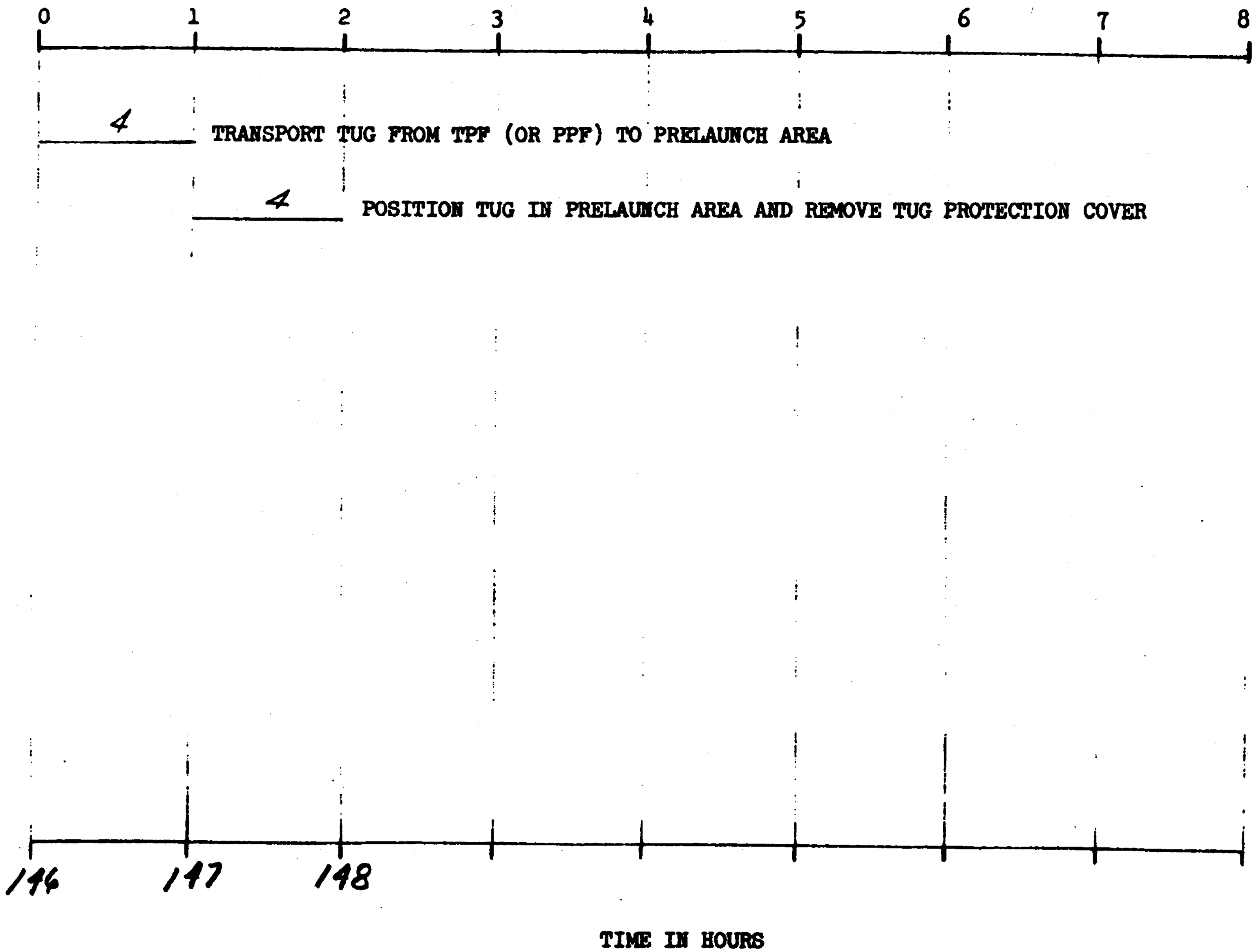
OPTION NUMBER 3F KSC	FUNCTION TITLE	REMOVE M&R GSE	FLOW BLOCK NO.	1.1.14



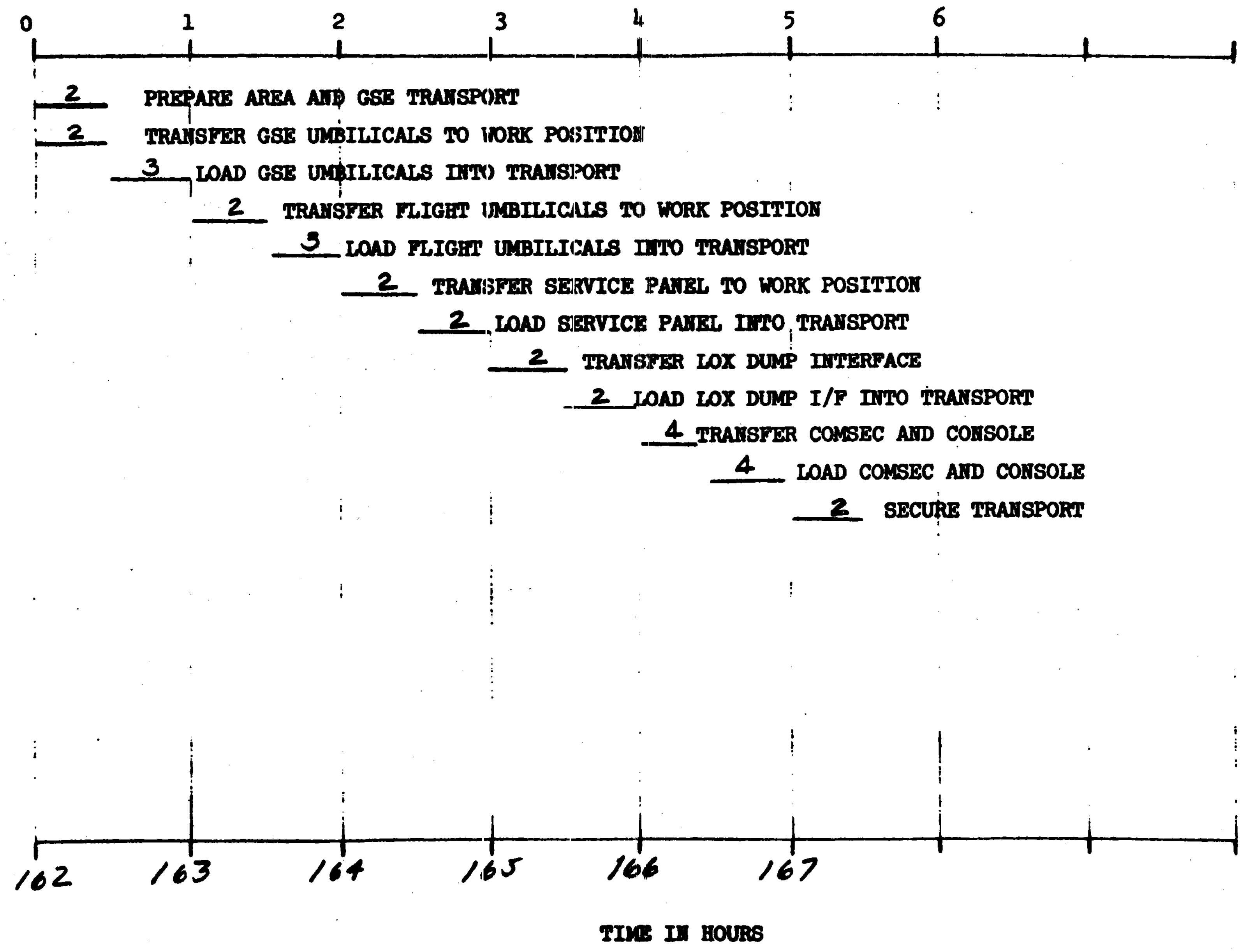
OPTION NUMBER	3F KSC	FUNCTION TITLE	PREPARE FOR TRANSPORT	FLOW BLOCK NO.	1.1.2 1



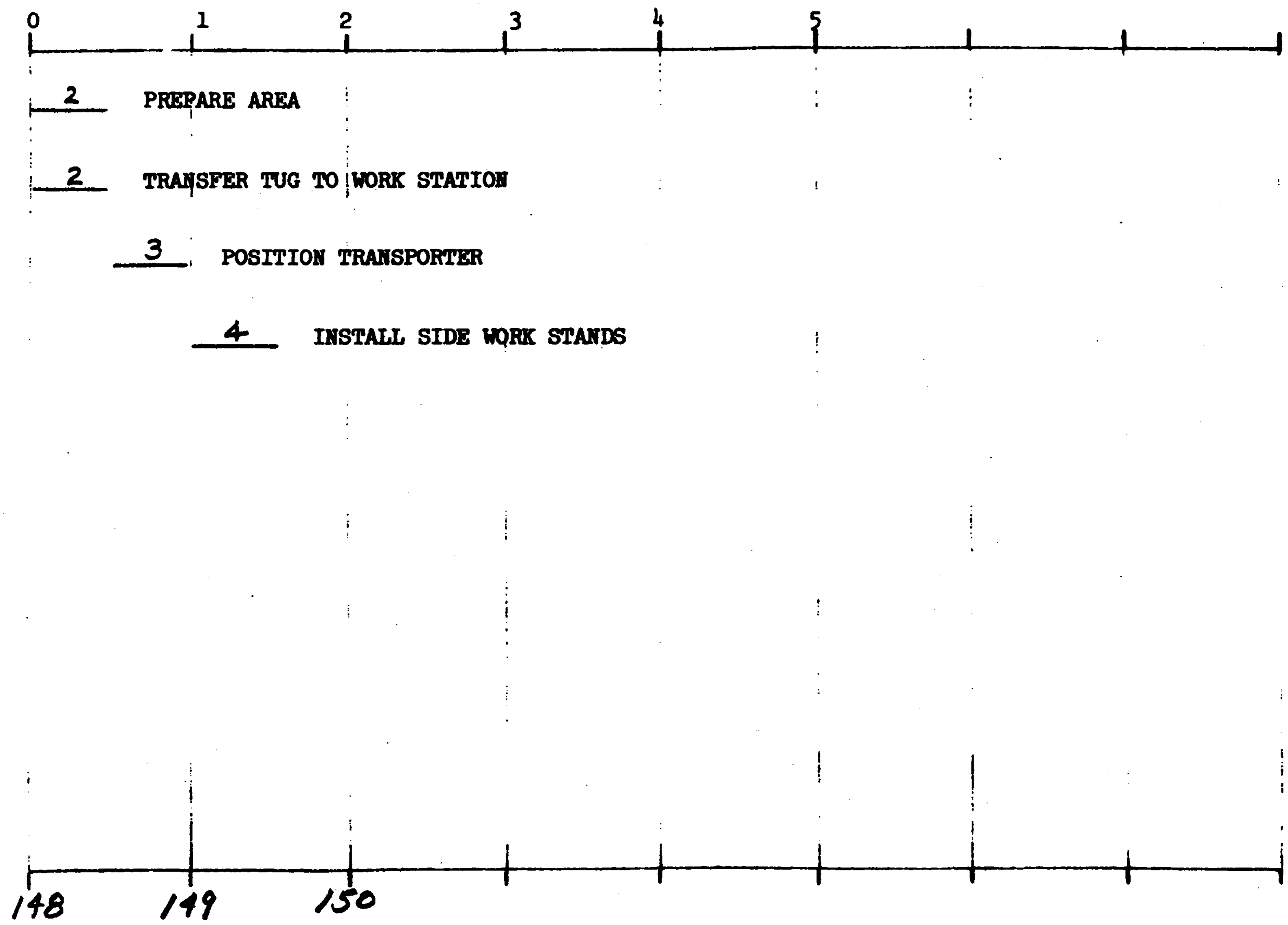
OPTION NUMBER	3F KSC	FUNCTION TITLE	TRANSFER TO PRELAUNCH	FLOW BLOCK NO.	1.1.2 6



OPTION NUMBER	3F KSC	FUNCTION TITLE	RECEIVE FSE FROM M&R	FLOW BLOCK NO.	2.1.1

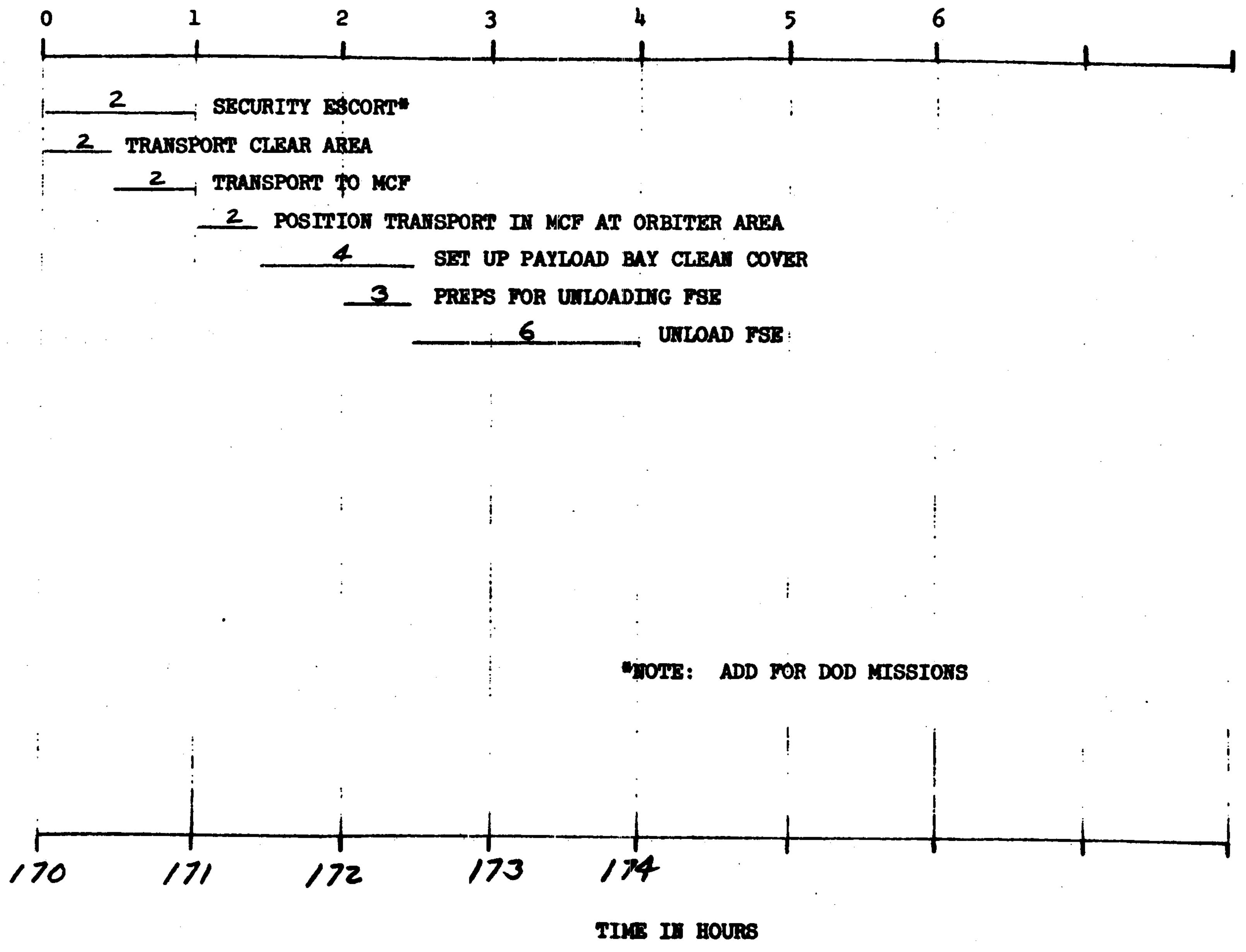


OPTION NUMBER 3F KSC	FUNCTION TITLE RECEIVE TUG FROM M&R	FLOW BLOCK NO. 2.1.2

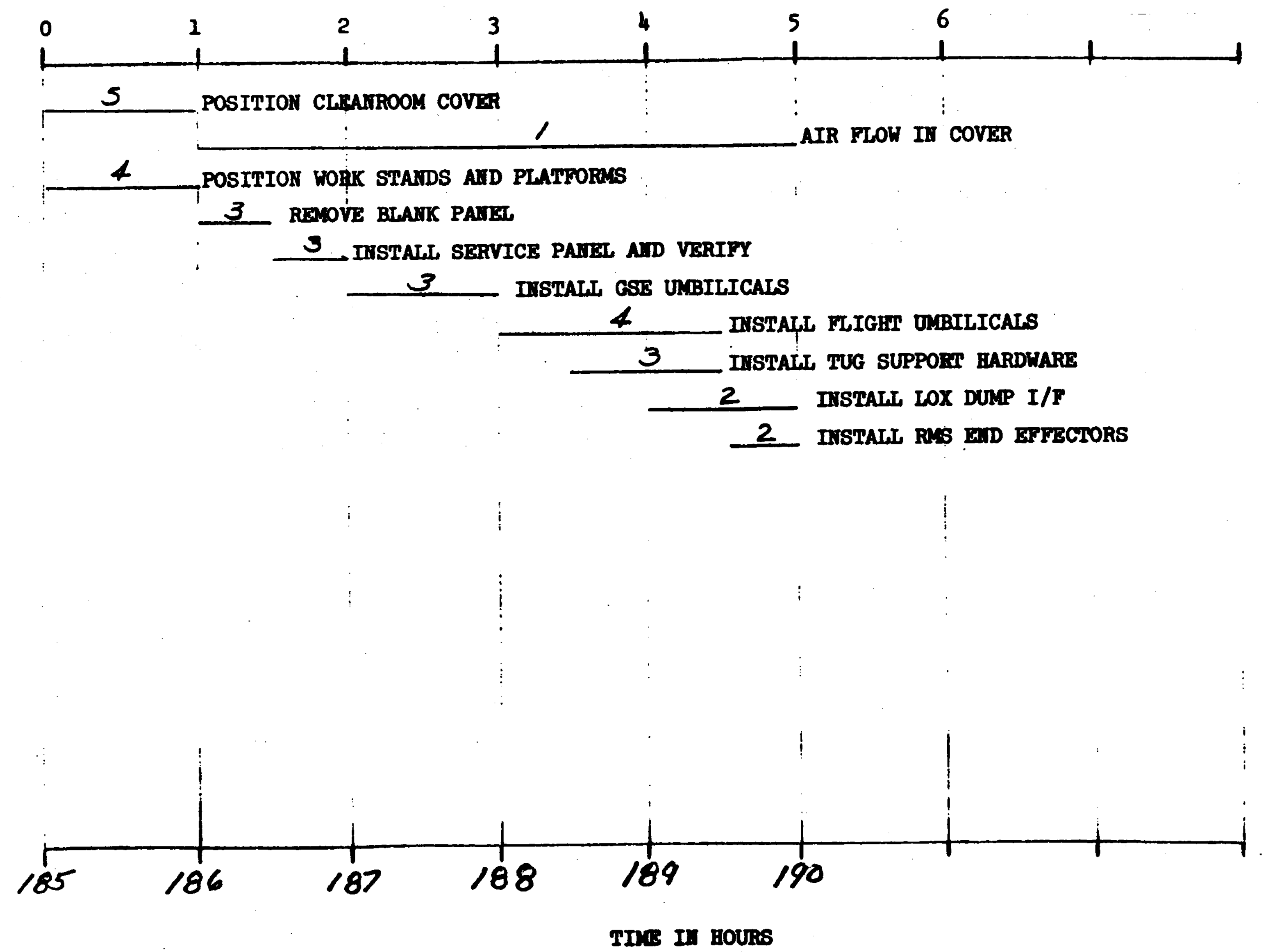


TIME IN HOURS

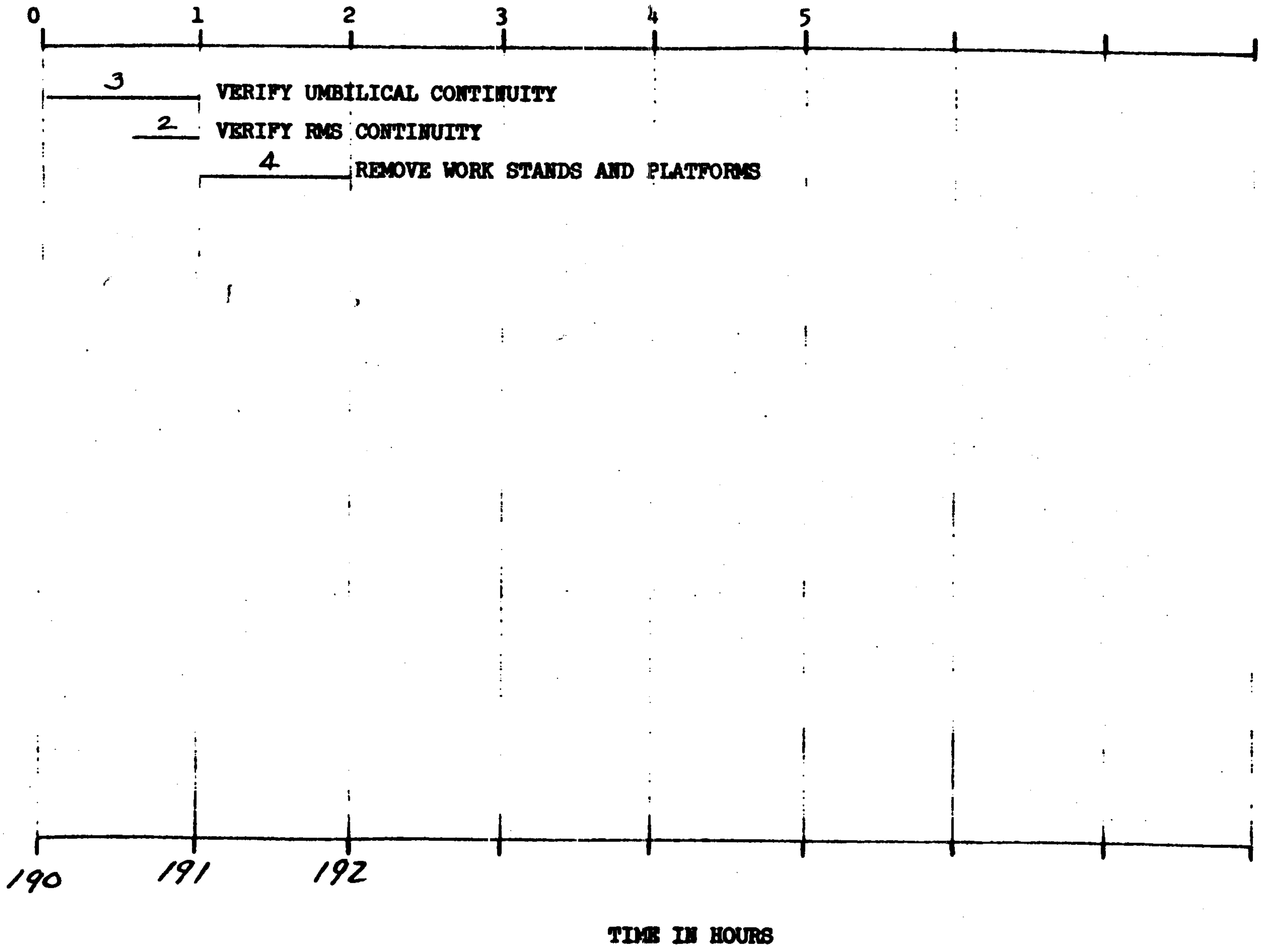
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F KSC	TRANSFER FSE TO MCF	2.3.1



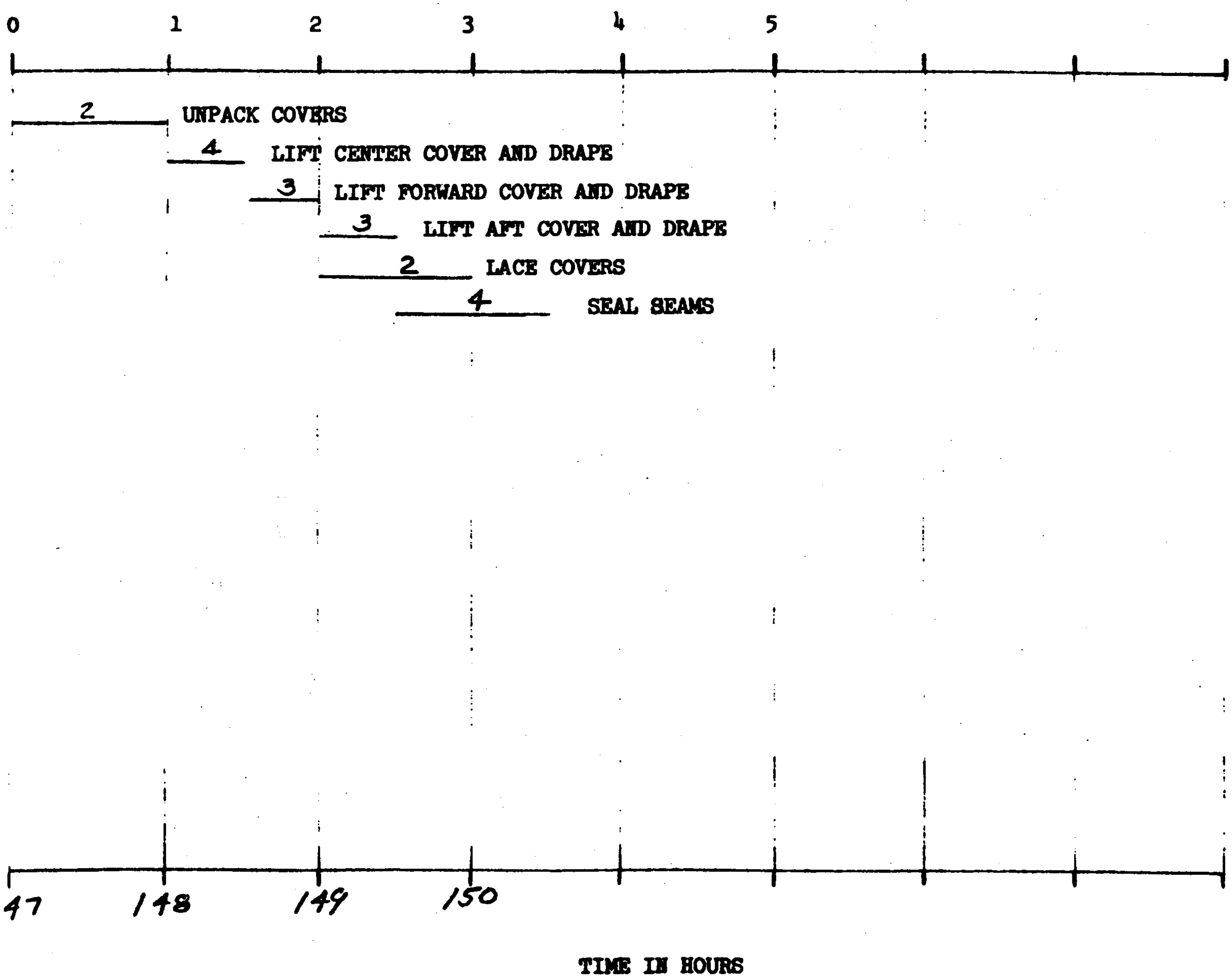
OPTION NUMBER 3F KSC	FUNCTION TITLE INSTALL FSE IN PAYLOAD BAY	FLOW BLOCK NO. 2.3.2.2



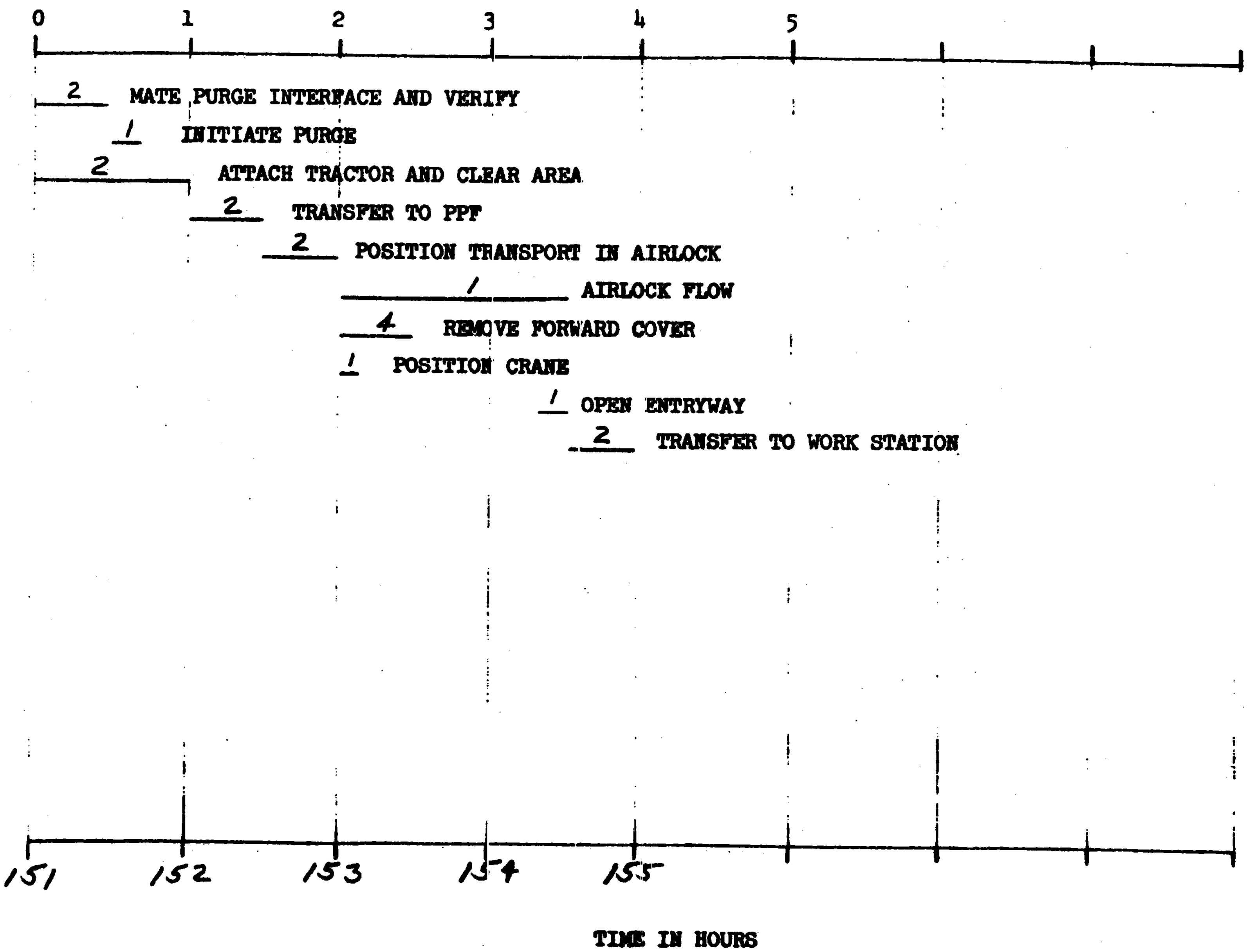
OPTION NUMBER	3F KSC	FUNCTION TITLE	VERIFY FSE INTERFACES	FLOW BLOCK NO.	2.3.3



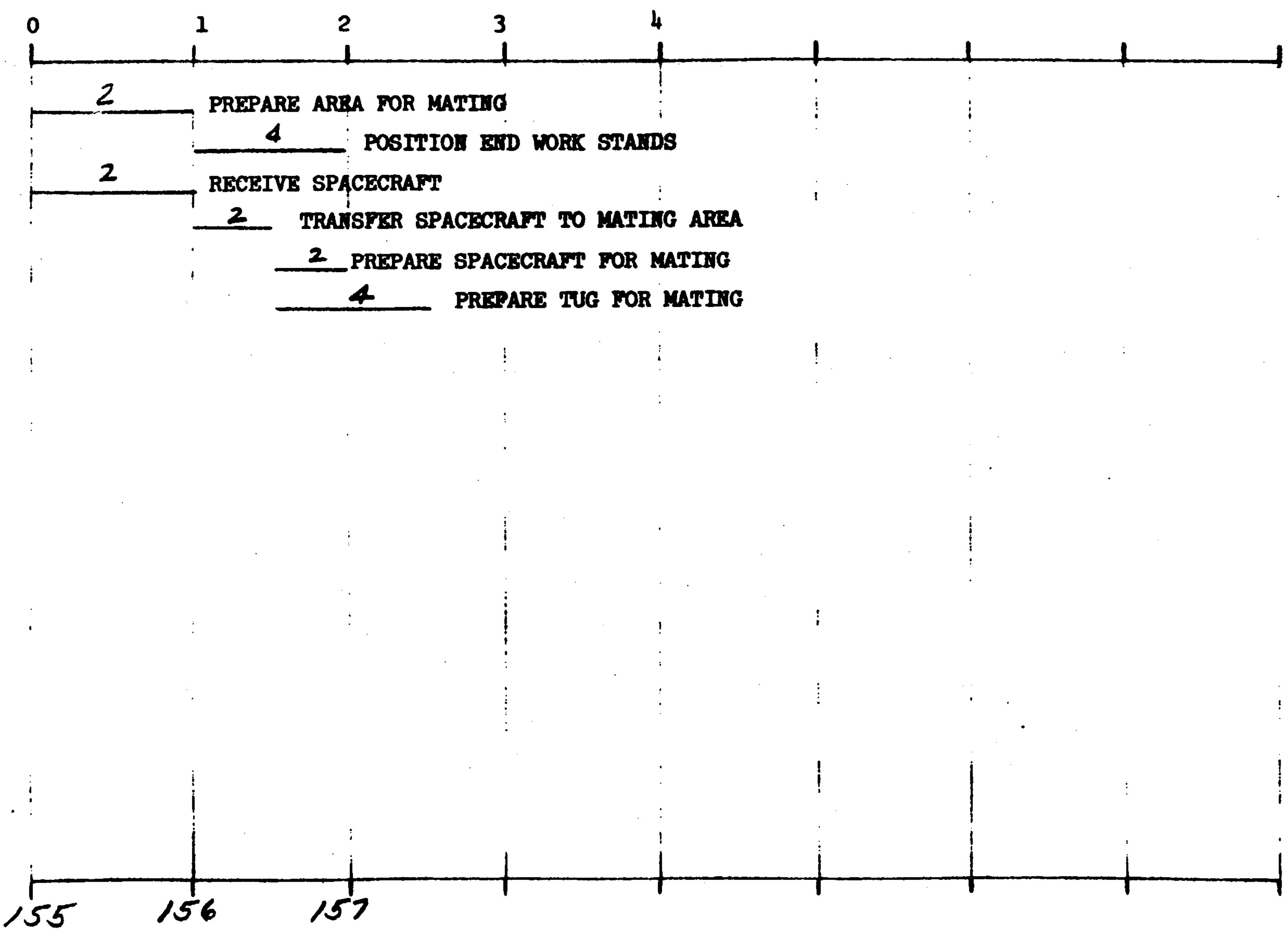
OPTION NUMBER 3F KSC	FUNCTION TITLE PREPARE TUG FOR PPF TRANSFER	FLOW BLOCK NO. 2.1.3



OPTION NUMBER 3F KSC	FUNCTION TITLE TRANSFER TUG TO PPF	FLOW BLOCK NO. 2.1.4

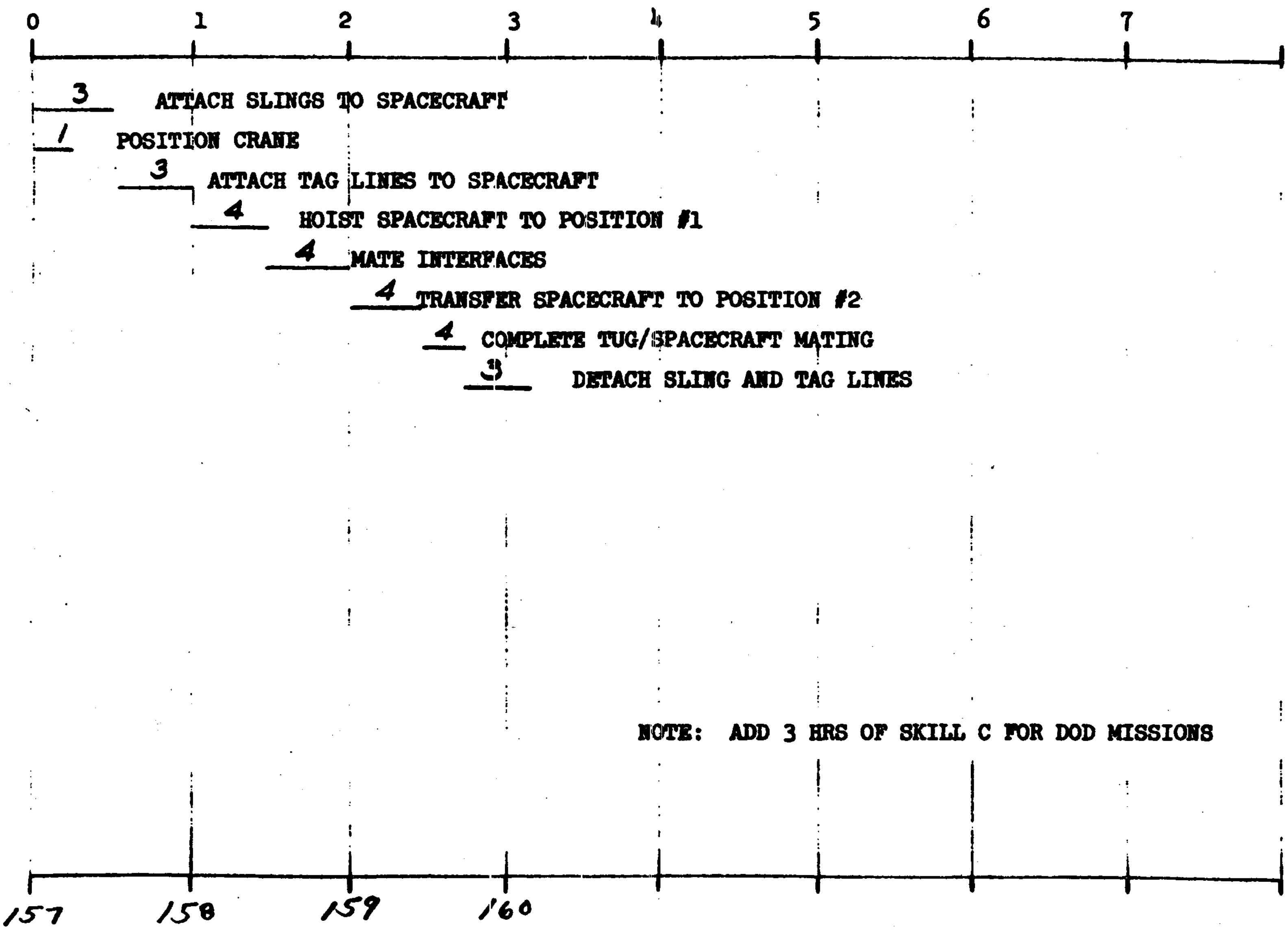


OPTION NUMBER 3F KSC	FUNCTION TITLE PREPARE TUG FOR SPACECRAFT	FLOW BLOCK NO. 2.2.2.a



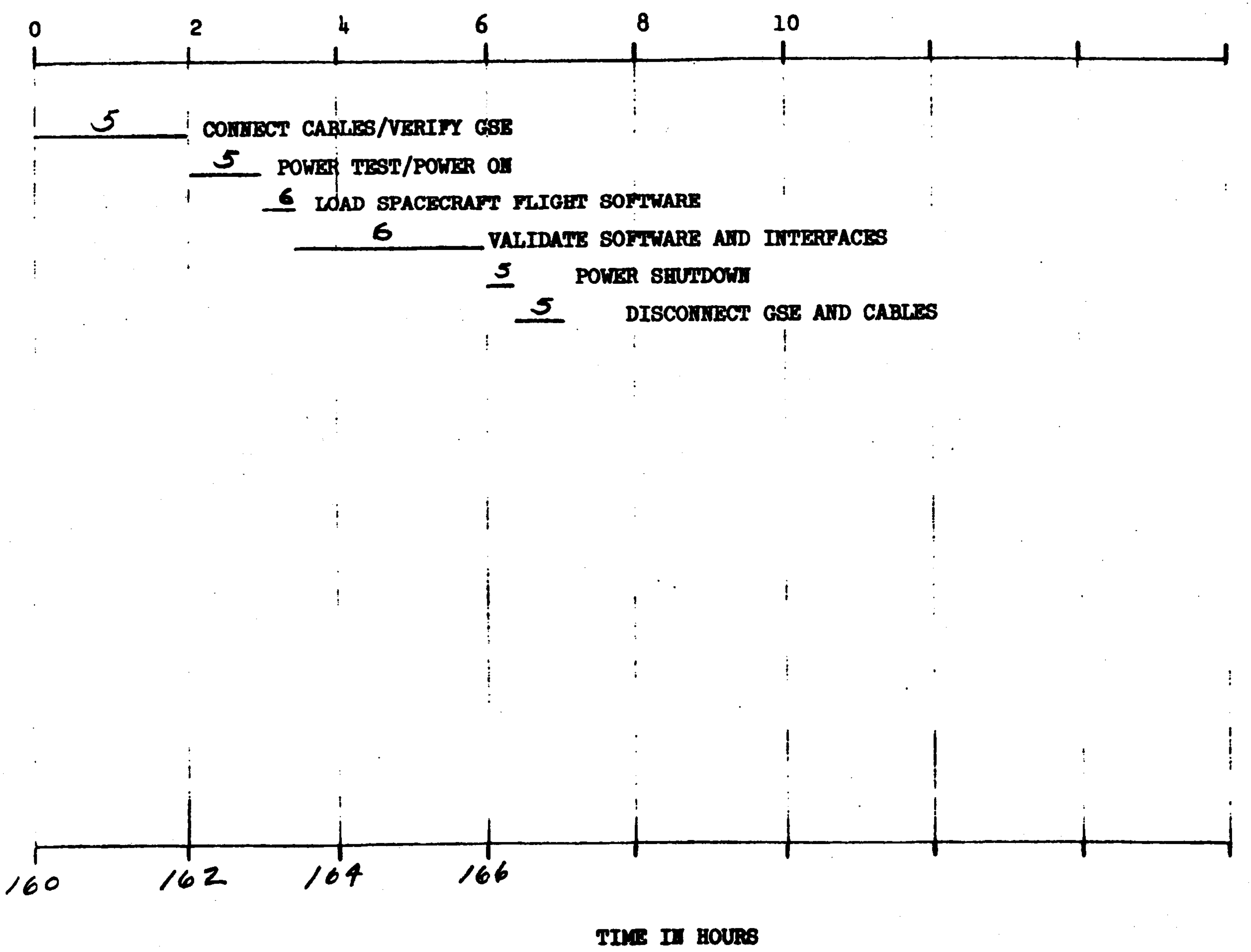
NOTE: NO KICK STAGE

OPTION NUMBER 3F KSC	FUNCTION TITLE MATE TUG AND SPACECRAFT	FLOW BLOCK NO. 2.2.3

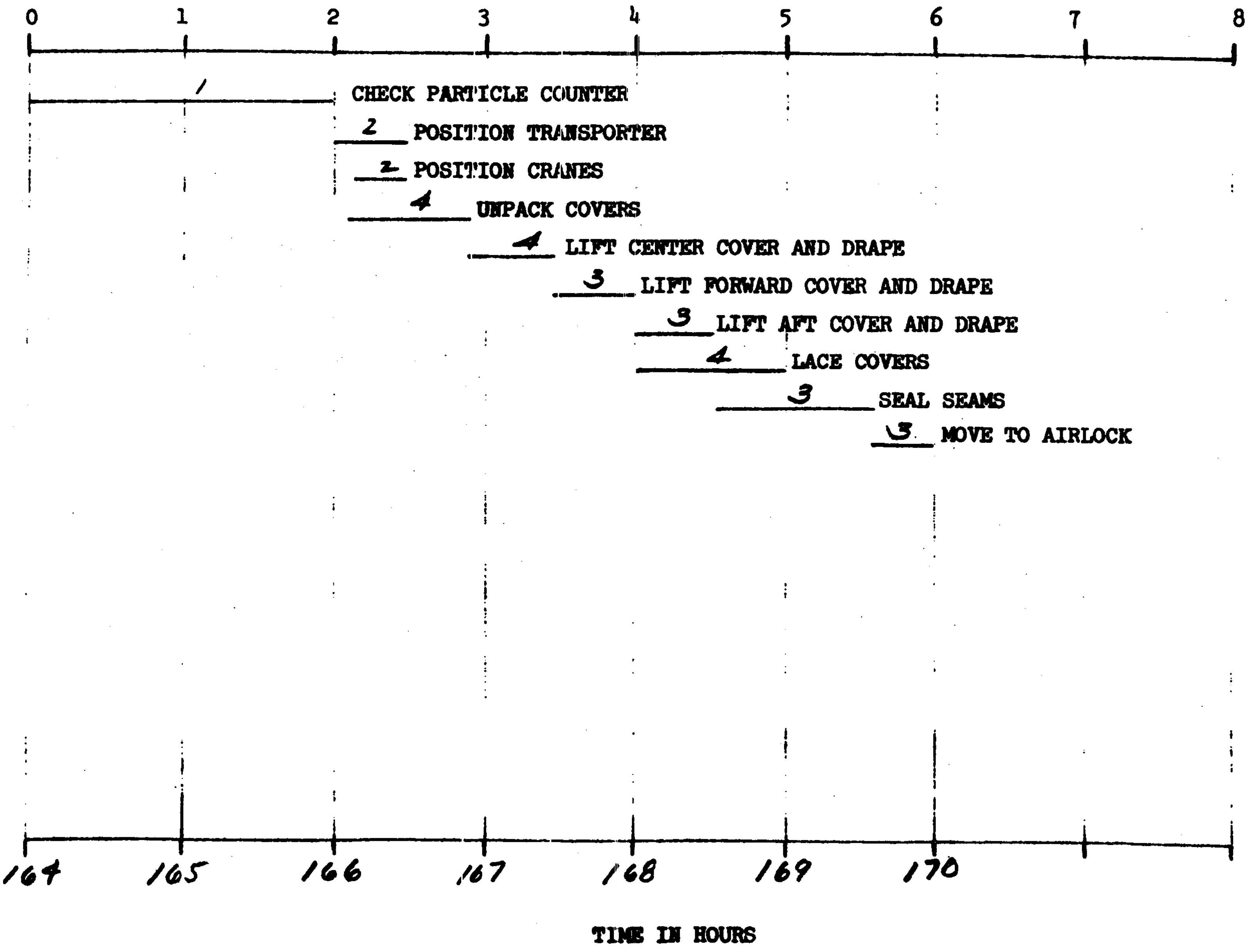


NOTE: ADD 3 HRS OF SKILL C FOR DOD MISSIONS

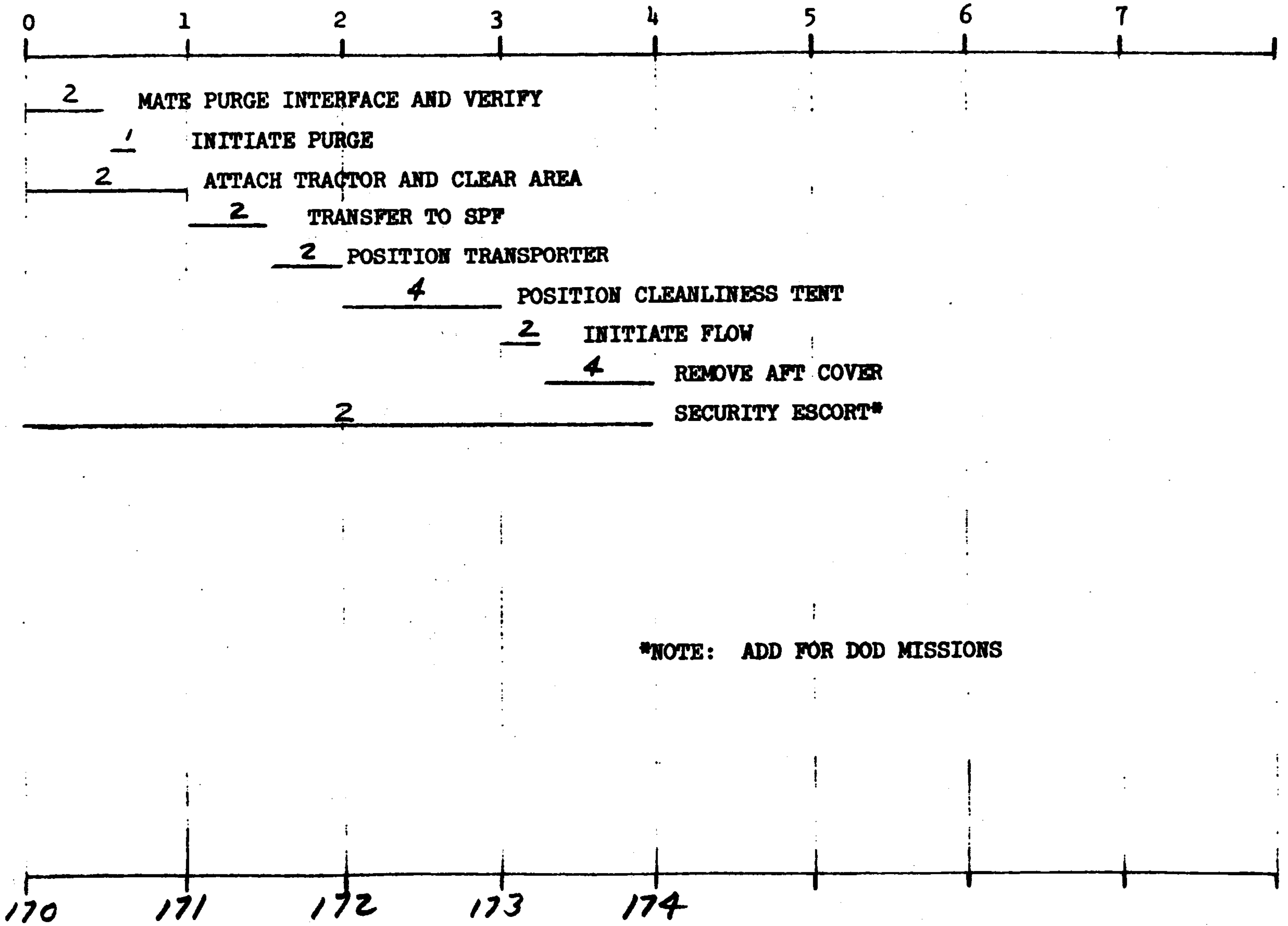
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F KSC	VERIFY TUG-TO-SPACECRAFT INTERFACES	2.2.4



OPTION NUMBER	3F KSC	FUNCTION TITLE	VERIFY CLEANLINESS	FLOW BLOCK NO.	2.2.5

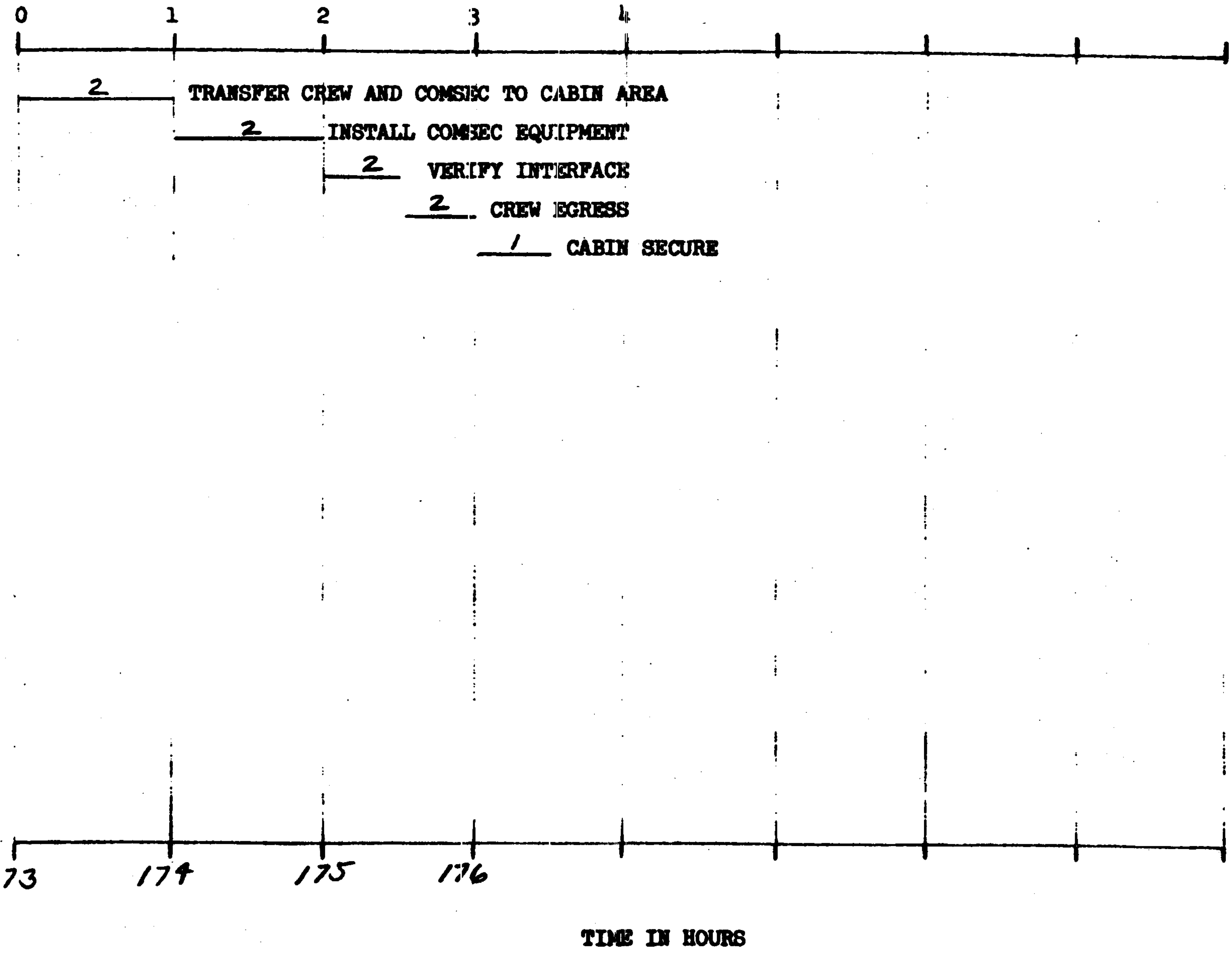


OPTION NUMBER 3F KSC	FUNCTION TITLE TRANSFER PAYLOAD TO SPF	FLOW BLOCK NO. 2.1.5

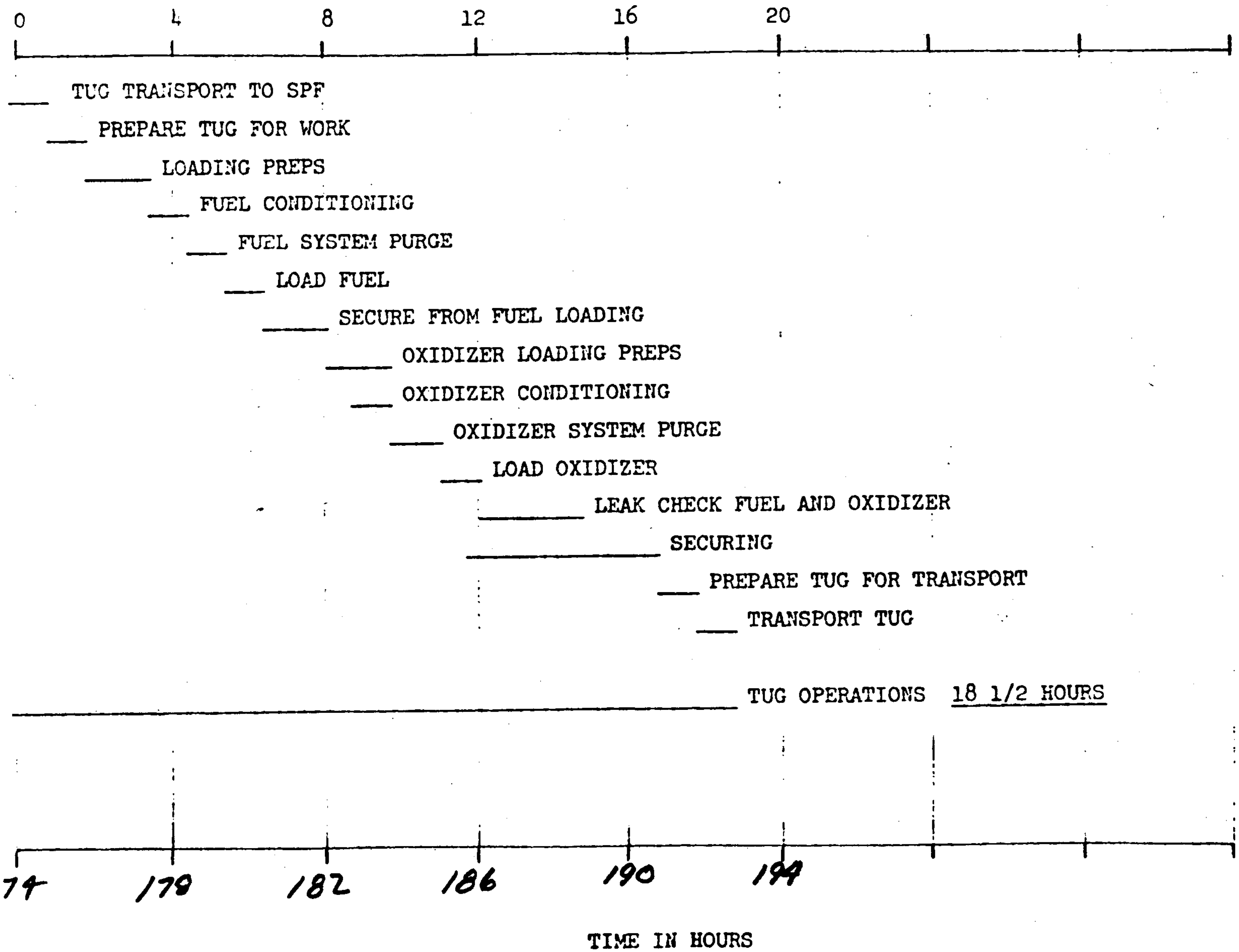


TIME IN HOURS

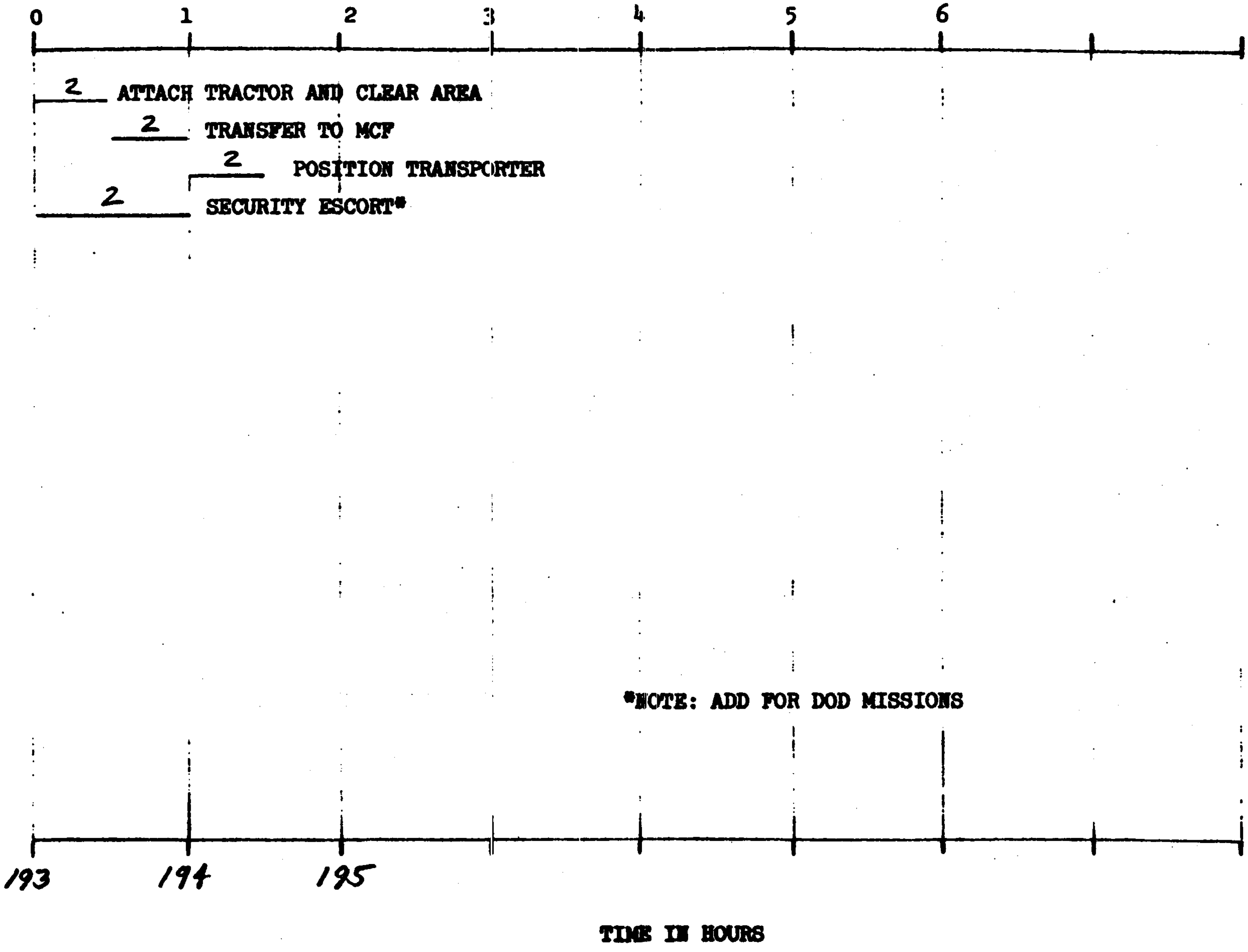
OPTION NUMBER 3F KSC	FUNCTION TITLE INSTALL GSE IN CABIN (COMSEC)	FLOW BLOCK NO. 2.3.2.1.b



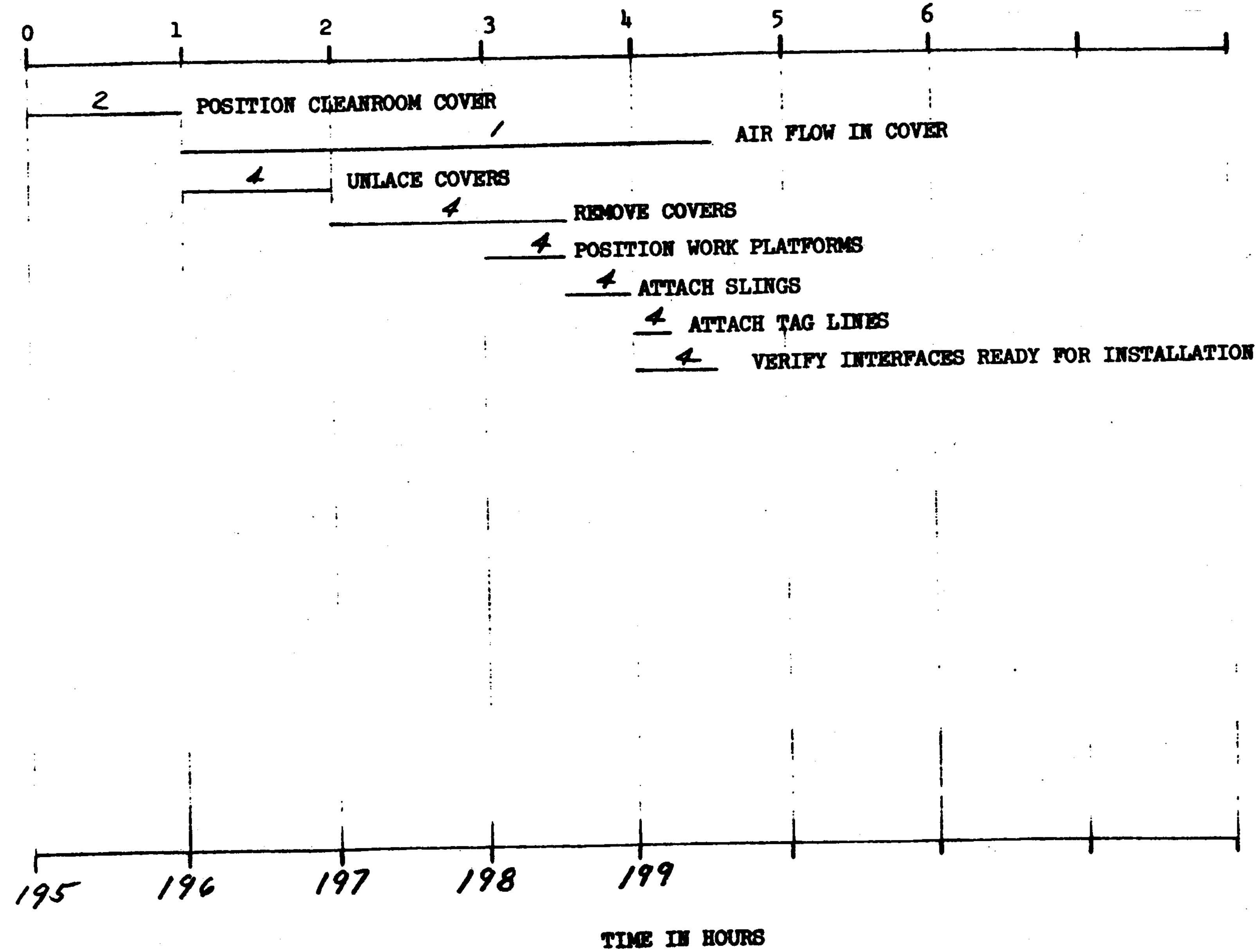
OPTION NUMBER 3F KSC	FUNCTION TITLE BIPROPELLANT APS LOADING AT SPF INTEGRAL SYSTEM	FLOW BLOCK NO. 2.1.8



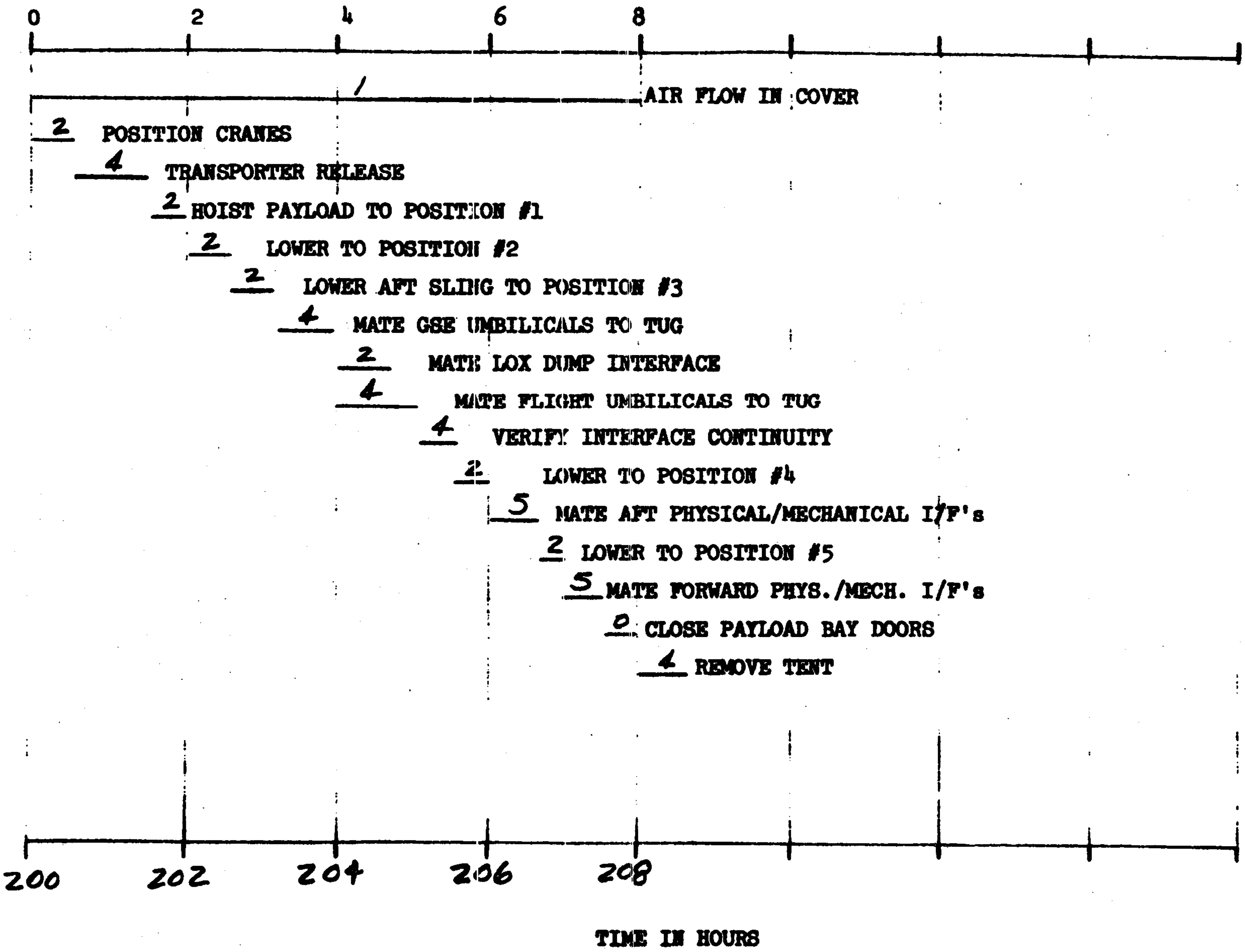
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F KSC	TRANSFER PAYLOAD TO MCF	2.3.4



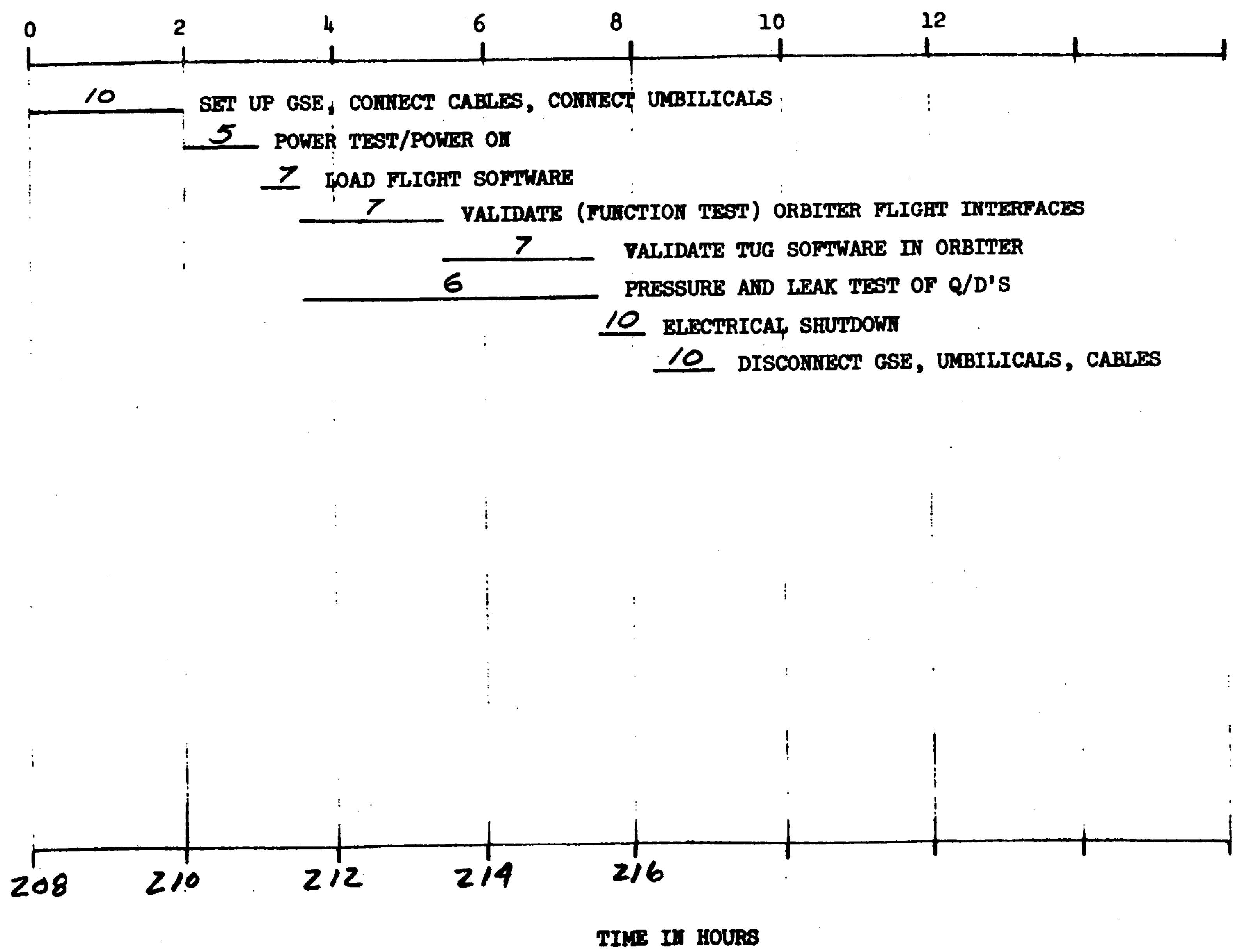
OPTION NUMBER 3F KSC	FUNCTION TITLE PAYLOAD INSTALLATION PREPS	FLOW BLOCK NO. 2.3.6



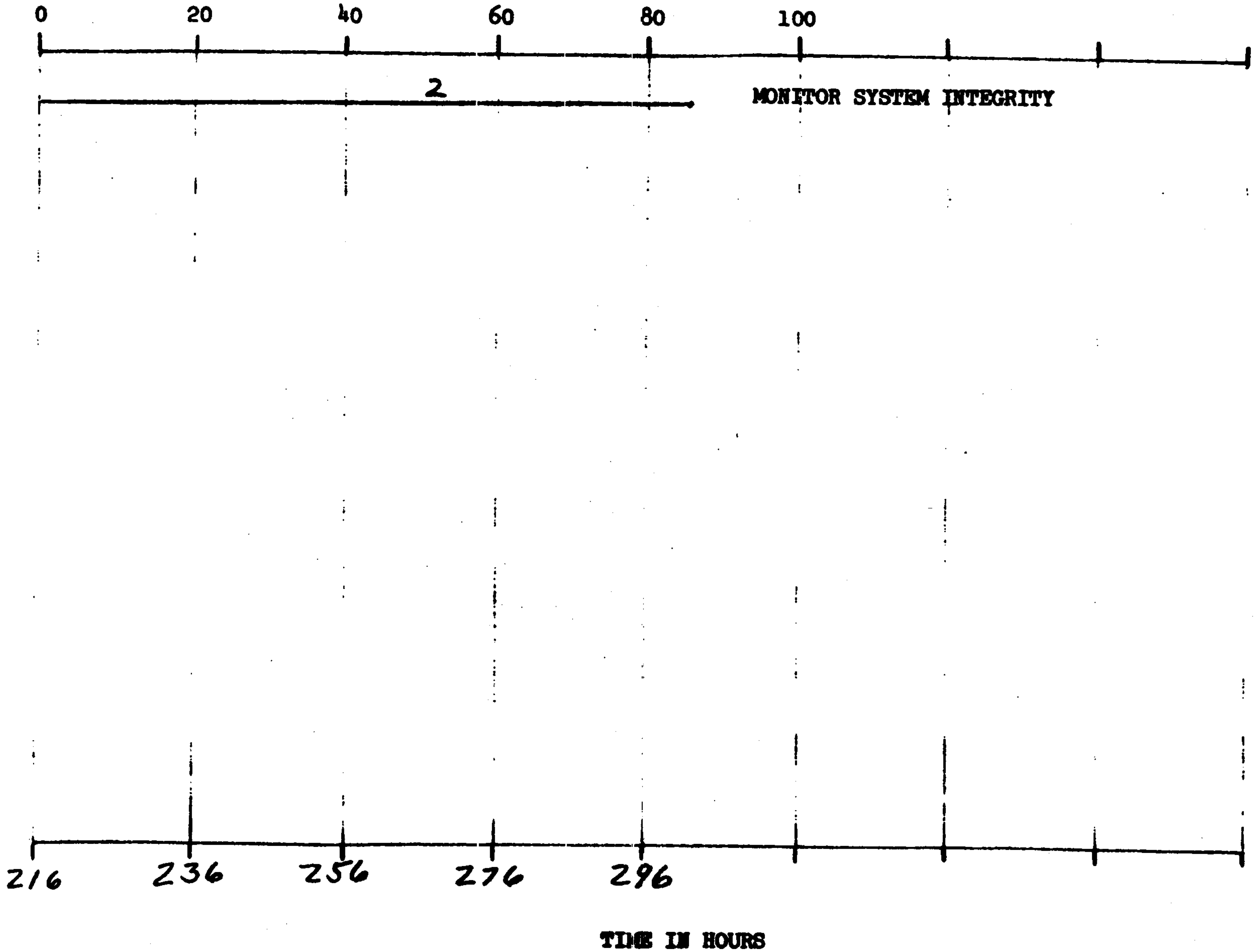
OPTION NUMBER 3F KSC	FUNCTION TITLE PAYLOAD INSTALLATION MCF	FLOW BLOCK NO. 2.3.7



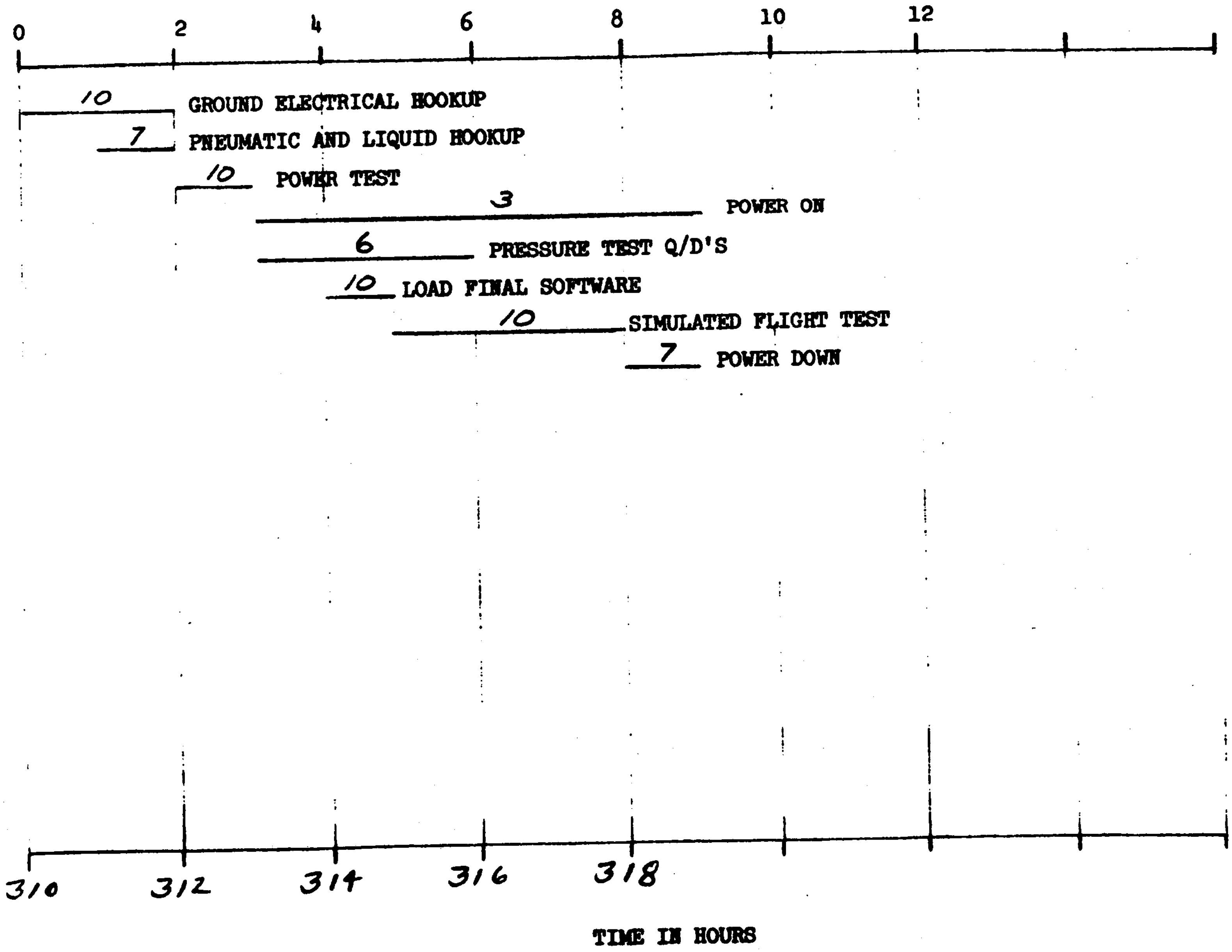
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F KSC	VERIFY PAYLOAD-TO-SHUTTLE INTERFACES	2.3.9



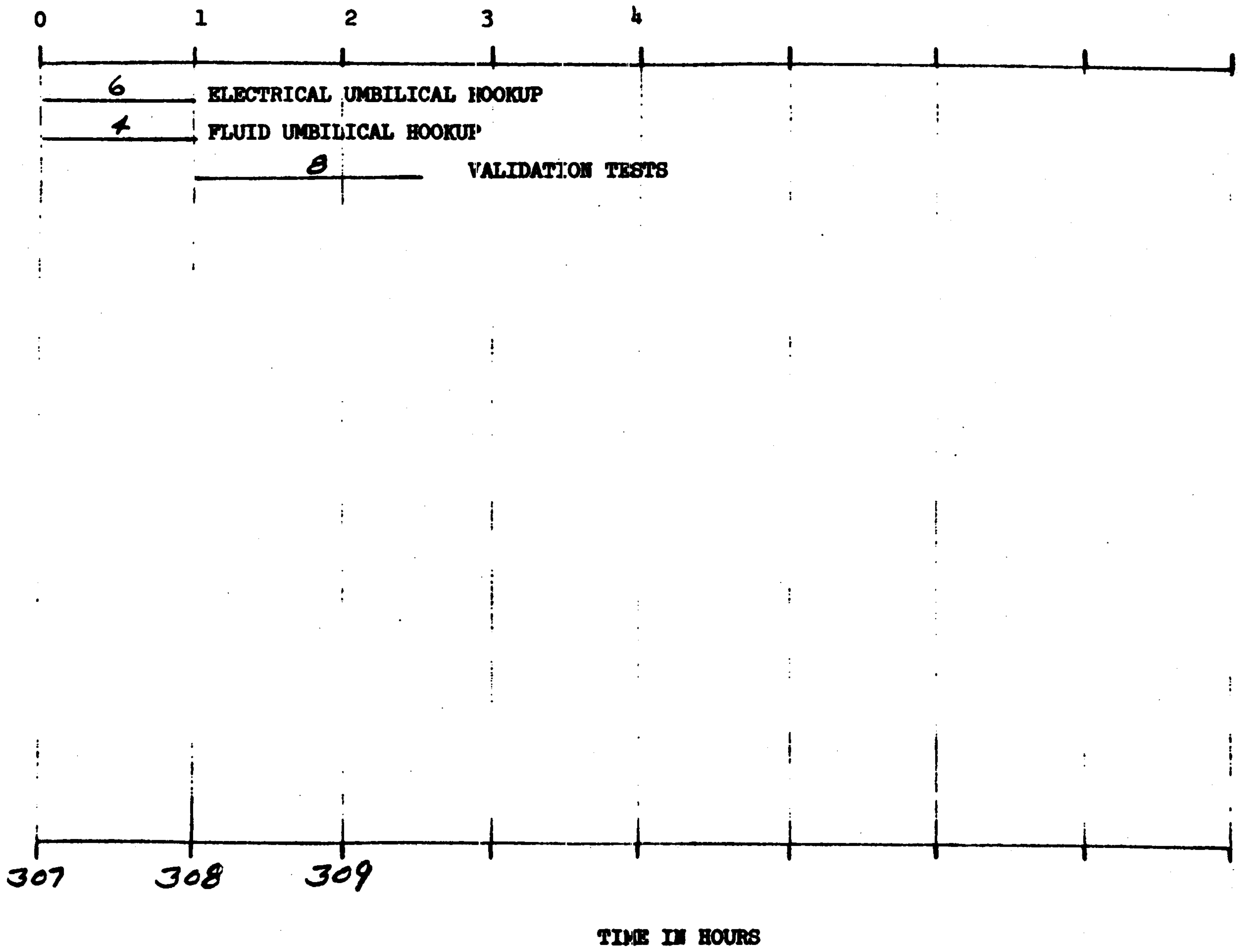
OPTION NUMBER 3F KSC	FUNCTION TITLE MONITOR STORABLE ACPS	FLOW BLOCK NO. 2.4.1.a



OPTION NUMBER 3F KSC	FUNCTION TITLE ORBITER/PAYLOAD INTEGRATION SYSTEM TEST	FLOW BLOCK NO. 2.4.1

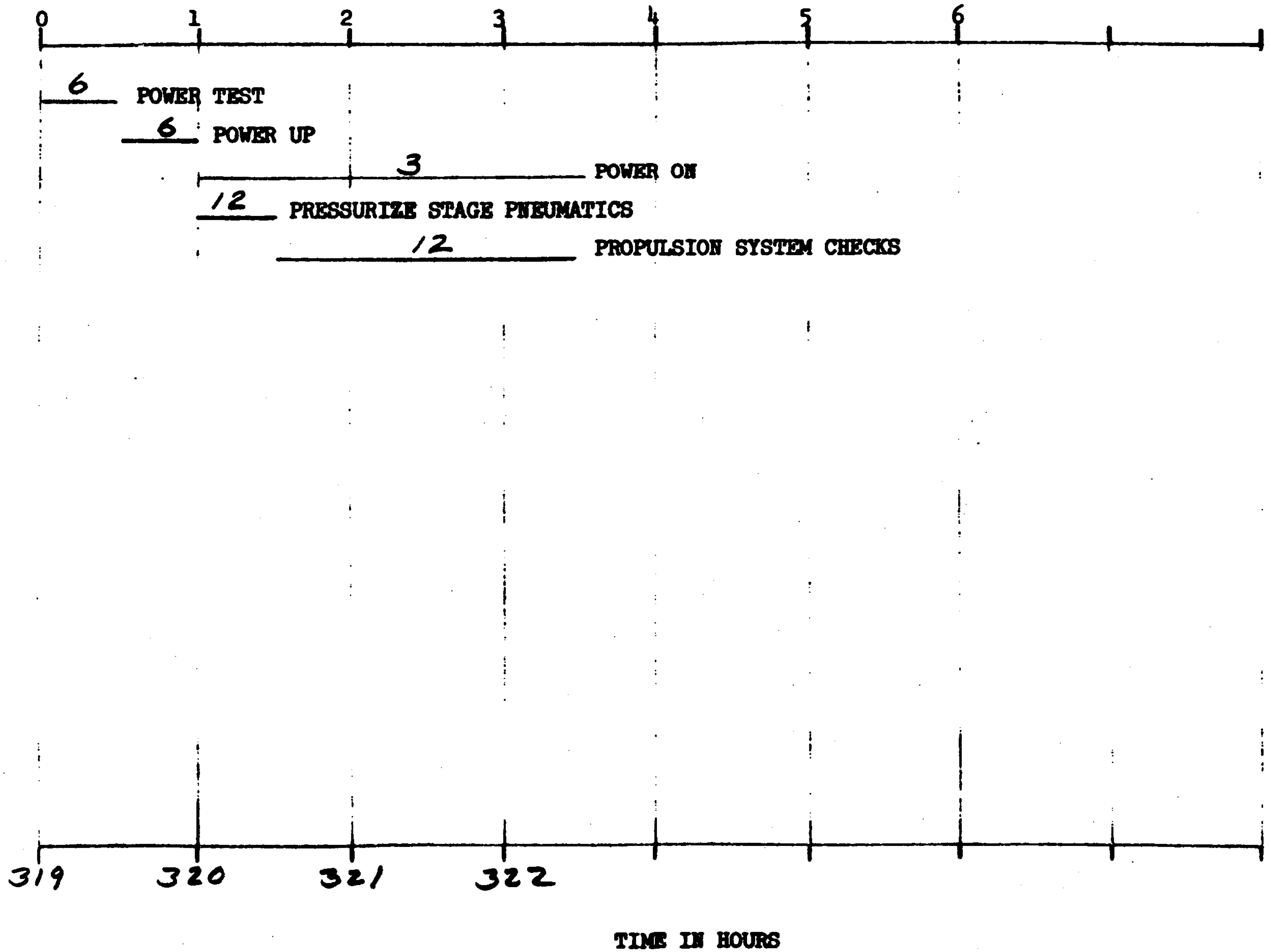


OPTION NUMBER 3F KSC	FUNCTION TITLE TUG SERVICE AT PAD (NON-CRYOS)	FLOW BLOCK NO. 2.4.2.a

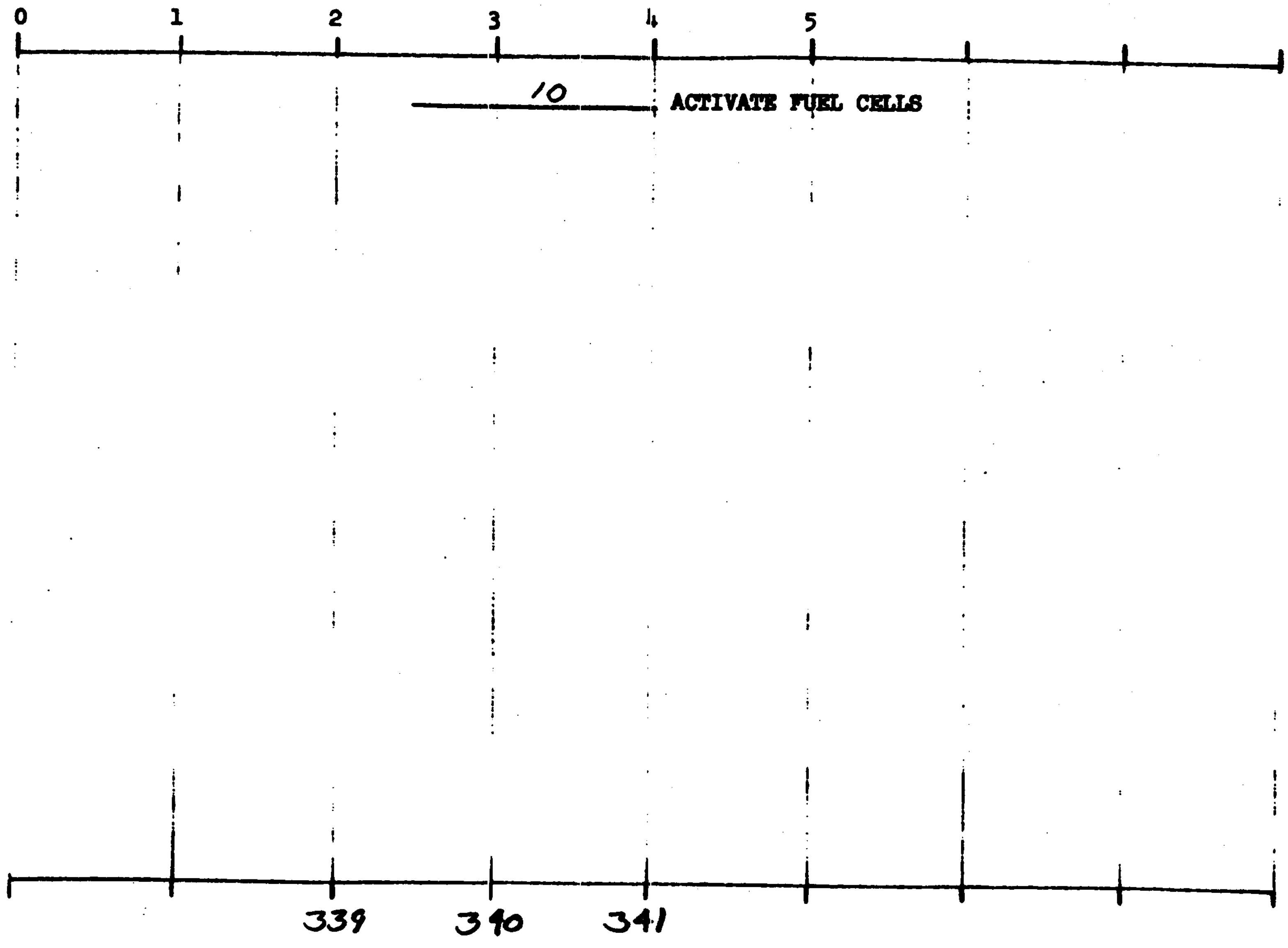


UMBILICAL HOOKUP

OPTION NUMBER 3F KSC	FUNCTION TITLE TUG SERVICE AT PAD (NON-CRYO)	FLOW BLOCK NO. 2.4.2.b

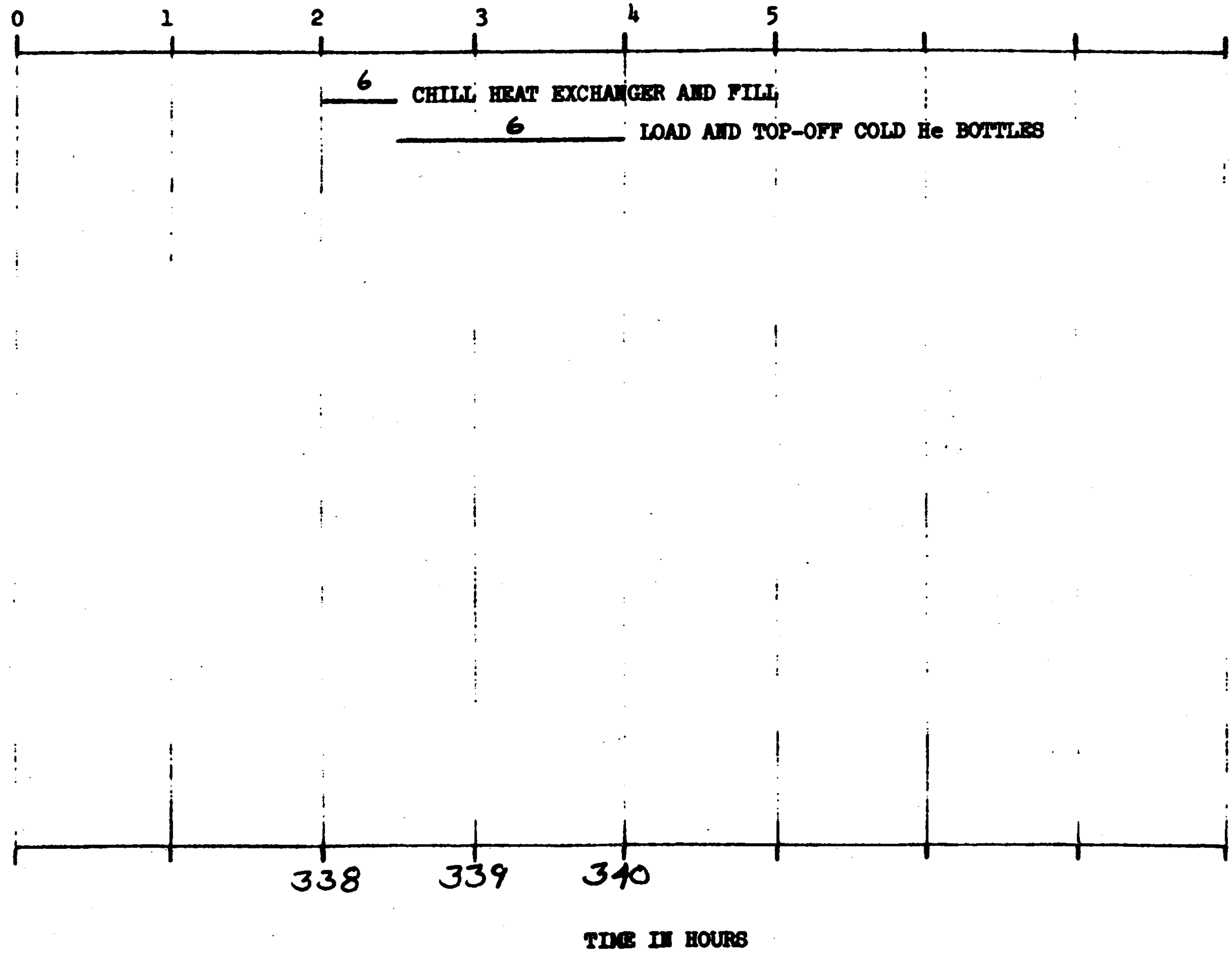


OPTION NUMBER	3F KSC	FUNCTION TITLE	TUG SERVICE AT PAD (CRYO'S)*	FLOW BLOCK NO.	2.4.3.a



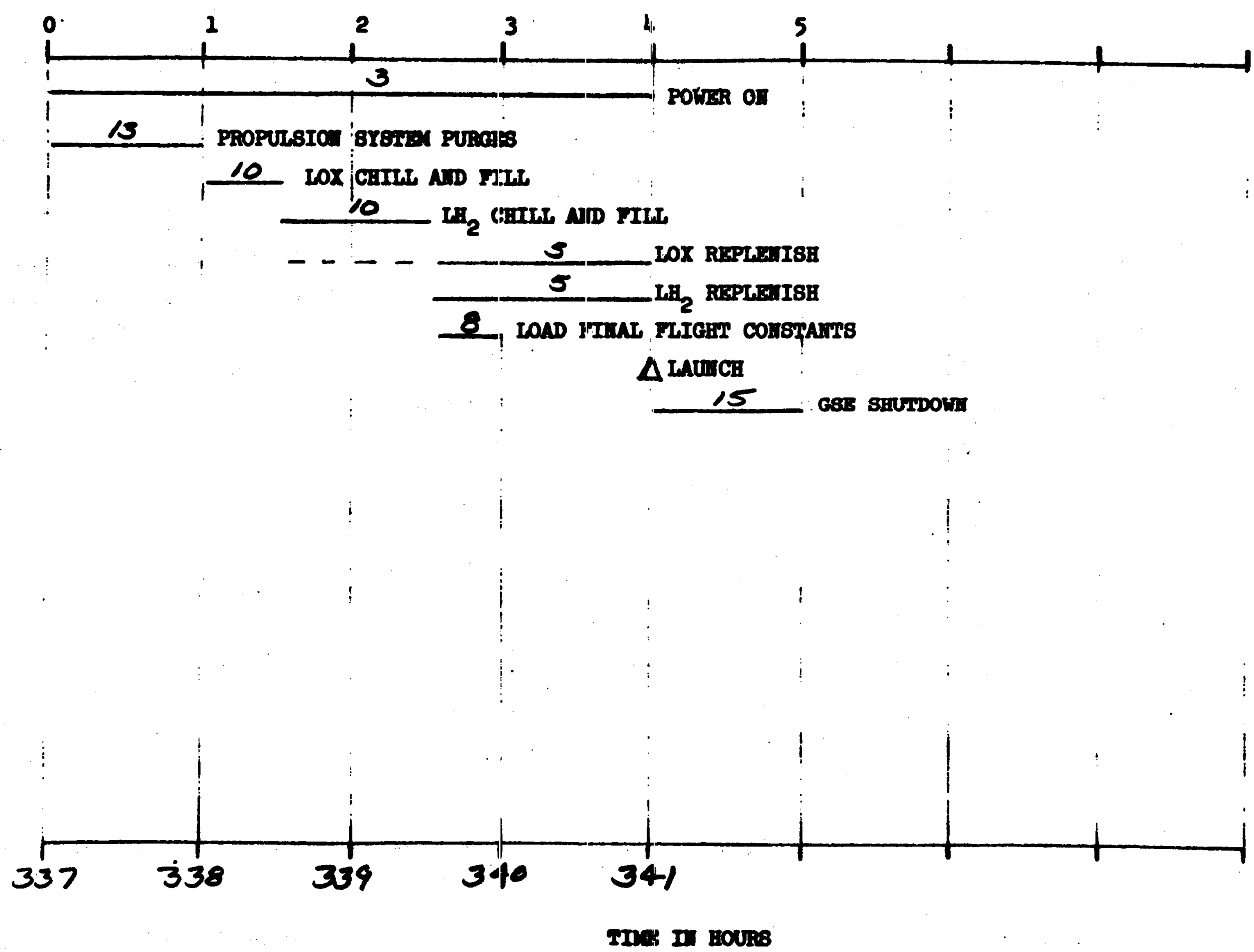
*FOR FUEL CELLS

OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F KSC	TUG SERVICE AT PAD (CRYO'S)*	2.4.3.b

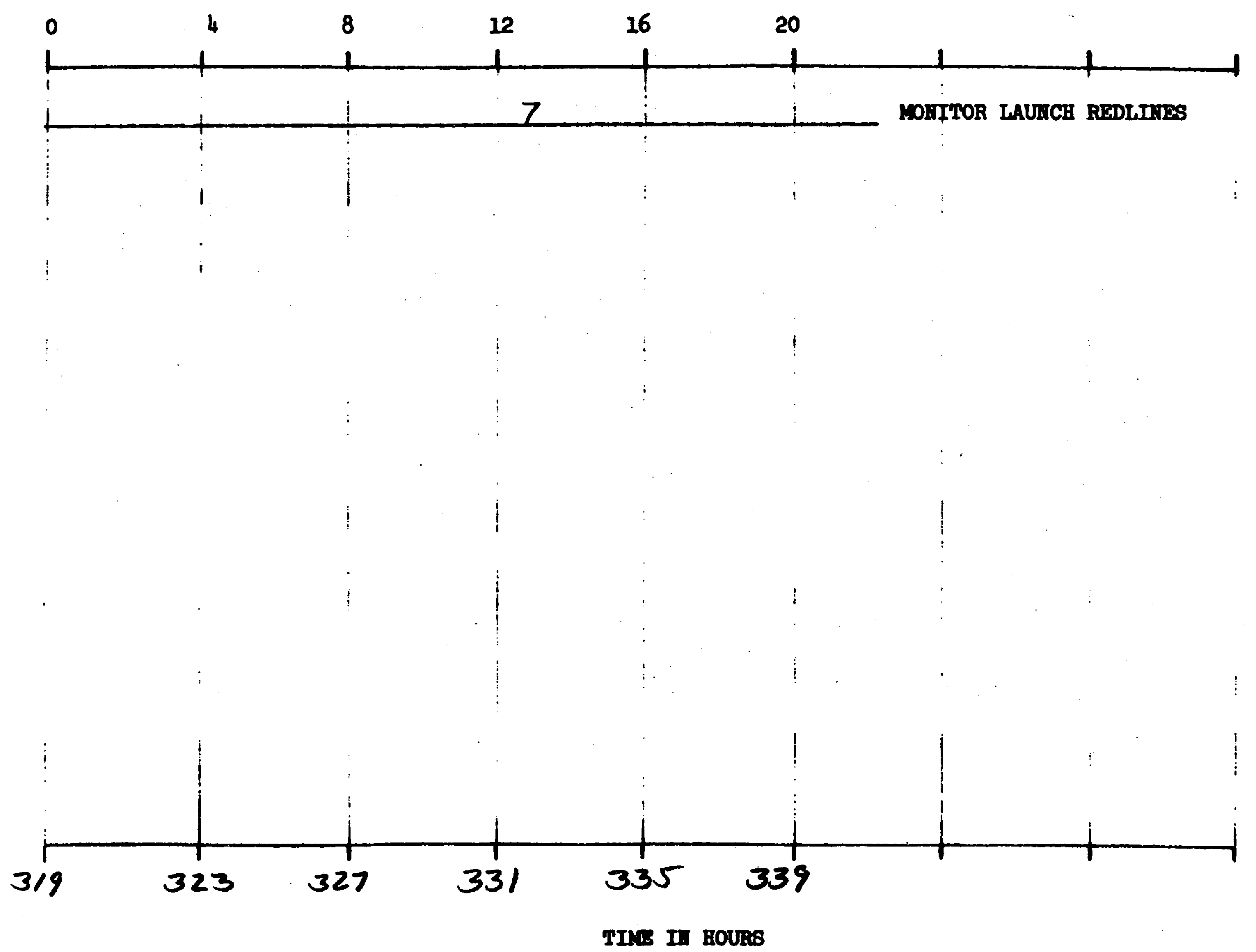


*FOR COLD HE PRESS. SYSTEM

OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
3F KSC	TUG SERVICE AT PAD (CRYO'S)	2.4.3



OPTION NUMBER 3F KSC	FUNCTION TITLE SUBSYSTEM MONITORING AT PAD	FLOW BLOCK NO. 2.4.4



ON PAD VERSUS OFF PAD INSTALLATION

(ACTION ITEM 139)

MDAC Approach

Tug/Shuttle mating is currently baselined to occur at the Shuttle maintenance and checkout facility 144 hours prior to launch. After installation has been completed, however, the Tug is essentially inaccessible until, after orbiter erection and mating with the external tank, the Shuttle is transported to the launch pad 88 hours later. If, however, the Tug/Shuttle mating is performed at the launch pad, the Tug turnaround schedule can be shortened by 11 shifts. Compression of Tug turnaround has no effect on ground crew size which is primarily dependent on annual launch rates, however, the active fleet size can be reduced as the turnaround time is shortened. If the Tug production fleet size can be reduced (affective substantial savings), on-pad installation is highly desirable.

MDAC Position

On-pad installation is highly desirable for Tug options 1 and 2 since production fleet size can be reduced by one Tug from 10 to 9 and 9 to 8 respectively.

Rationale

The Tug production fleet size is based on equal usage of each Tug and the number of Tugs required during the last program year. Additionally during the last program year, for each Tug option one Tug es expended during the middle of the year which has the effect of reducing the flight capability of one Tug by 50%.

Figure 1 illustrates

a) Tug active fleet size requirements for MCF and on pad installation versus annual launch rate.
b) the launch rate spectrum for each Tug option
c) identification of launch rate and required number of Tugs during the last program year for each Tug option.

Table 1 indicates launch rate and number of Tugs required during the last program year for each Tug option.

TUG OPTION	LAUNCH RATE	NO. OF TUGS
1	20	3
2	35	4
3I	36	4
3F	40	5

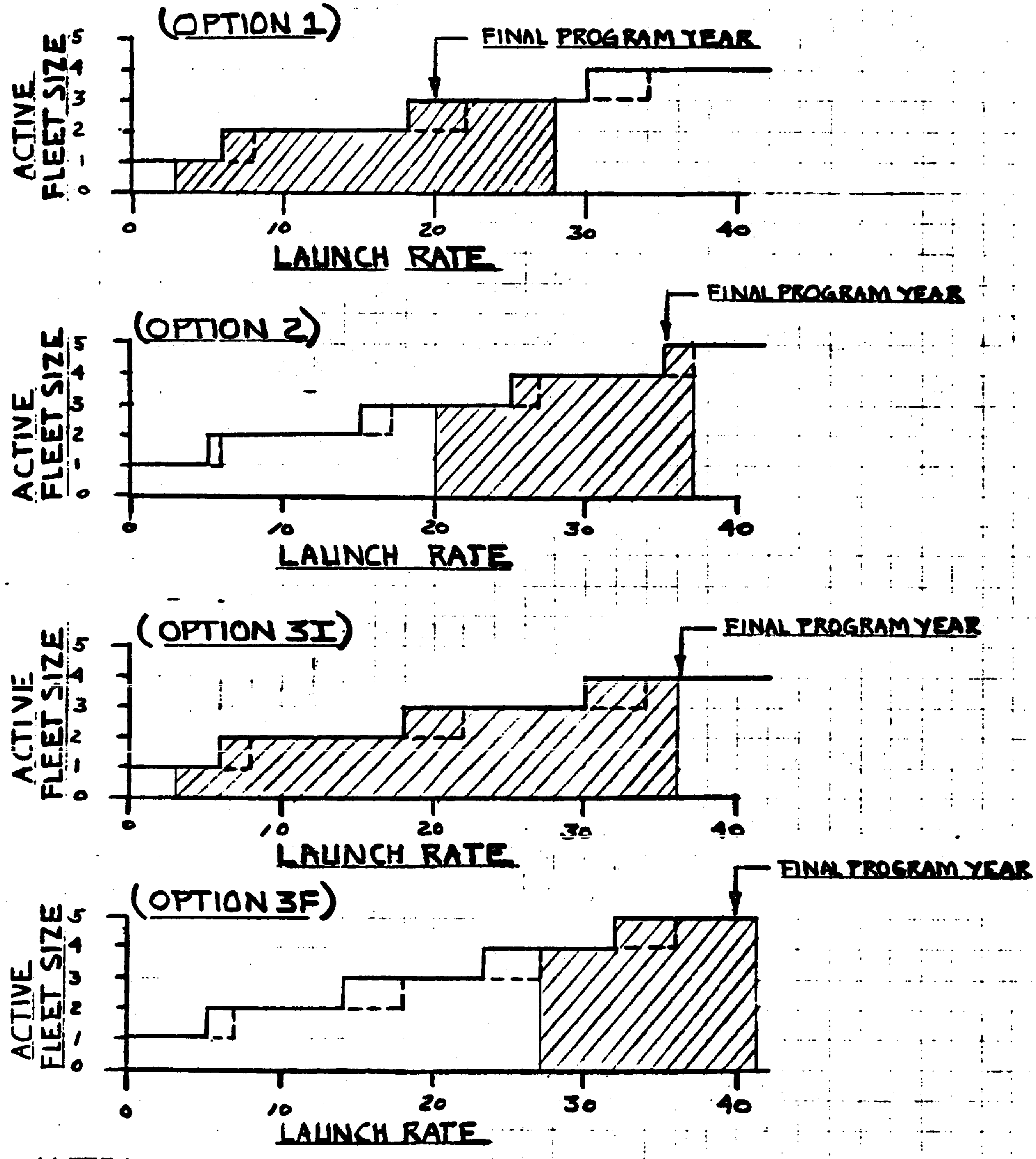
By comparing Table 1 with Figure 1, it can be seen that for options 1 and 2, during the last program year, the active fleet and therefore the production fleet size can be reduced by one Tug.

The production fleet size for Tug Option 3 is however not sensitive to a turn-around compression of 11 shifts and the time and location of Tug/Shuttle mating has no effect on the number of production Tugs required to satisfy program needs.

Impact

In addition to eliminating the requirement for on Tug in Options 1 and 2 (and the accompanying cost savings) additional substantial savings can be accomplished if installation occurs at the launch pad by eliminating the requirement for Tug/Shuttle GSE at the MCF. (Refer to Tug/Shuttle Demate and Safing Area versus Shuttle MCF.)

ON-PAD VERSUS MCF INSTALLATION IMPACT ON FLEET SIZE



NOTES:

- LAUNCH RATE SPECTRUM FOR EACH OPTION
- (---) ON-PAD INSTALLATION
- (——) MCF INSTALLATION

FIGURE 1

TUG/SHUTTLE DEMATE AT SAFING AREA
VERSUS SHUTTLE MCF
(ACTION ITEM 98)

MDAC Approach

Review of the functional timelines (3.2.3 versus 3.2.2) indicates that the Tug vehicle can realize a seven hour savings by removal at the safing area versus the Shuttle MCF.

MDAC Position

Recover returning payload at safing area if payload/Shuttle integrations occurs at the launch pad instead of at the Shuttle maintenance and checkout facility.

Rationale

If payload/Shuttle integration occurs at the launch pad a substantial savings in Shuttle/Tug GSE can be affected since

1) Shuttle/Tug integration and checkout GSE is no longer required at the MCF and equivalent GSE located at the launch pad will be utilized for on pad installation and post installation checks.

2) Shuttle/Tug demate GSE is no longer required at the MCF and Shuttle provided demate GSE at the safing area will be utilized.

Recovery at the Safing Area is no more or less complex, requires no more or less equipment, and requires no more or less men than recovery at the Shuttle MCF.

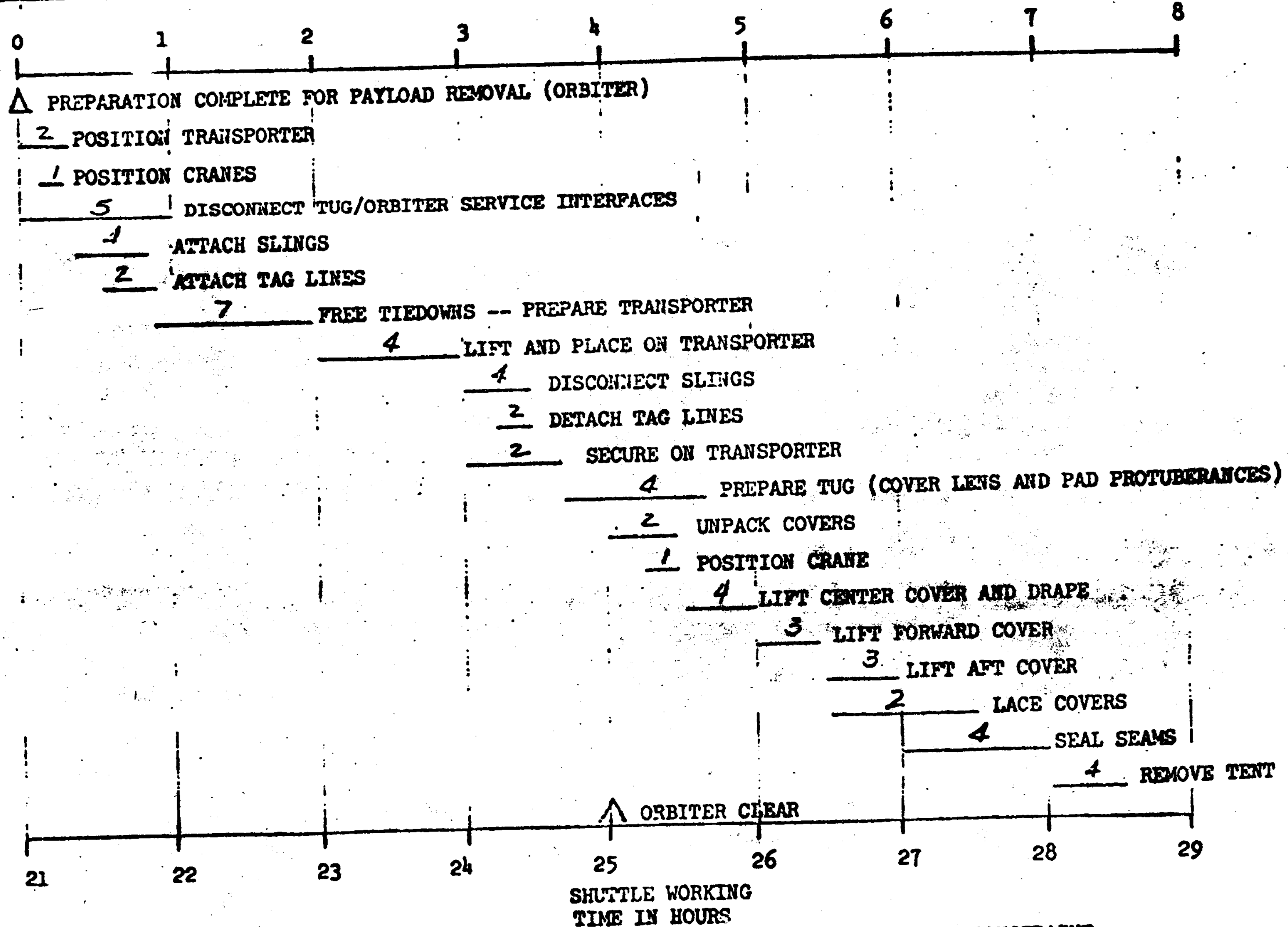
Reduction of Tug turnaround time by seven hours if Tug/Shuttle demate is accomplished at the Safing Area has no effect on the Tug program active fleet size or ground crew size. Since neither active fleet nor ground crew size is affected, the seven hours saved provides program planners with a seven hour pad with which to account for potential variances in the actual ground operations task times.

Impacts

The Shuttle ground flow will require change to show this approach, however, since the Shuttle is providing for the capability (reference data package, page 50, paragraph B.2) there will be no inpacts to the Shuttle program or planned facilities.

Figure 1

OPTION NUMBER	FUNCTION TITLE RECOVER TUG AT MCF	FLOW BLOCK NO. 3.2.3



SHUTTLE CONSTRAINT

NOT TWO CRANE OPERATORS PROVIDED BY SHUTTLE

4 11-288

Figure 2

OPTION NUMBER	FUNCTION TITLE: RECOVER TUG AT SAFING AREA	FLOW BLOCK NO. 3.2.2

0 2 4 6 8 10

TUG SAFING

2 POSITION TRANSPORTER

4 SET UP CLEANLINESS TENT

0 OPEN PAYLOAD BAY DOORS

5 DISCONNECT TUG/ORBITER INTERFACES

4 ATTACH SLINGS

2 ATTACH TAG LINES

7 FREE TIEDOWNS

4 REMOVE TUG AND PLACE ON TRANSPORTER

4 DISCONNECT SLINGS

2 DETACH TAG LINES

2 SECURE ON TRANSPORTER

10 PREPARE TUG AND REMOVE STANDS

3 COVER TUG

3 SEAL COVERS

0 CLOSE PAYLOAD BAY DOORS

▲ ORBITER CLEAR REQUIREMENTS - - - - ORBITER CLEARED

10 12 14 16 18 20 22 24

SHUTTLE WORKING TIME IN HOURS

▲ SHUTTLE CONSTRAINTS

11.3.8 Manning Requirements

Total manpower requirements and skill mix as ETR and WTR are shown in Figure 11.3.8-1 through 11.3.8-4. The year to year variation in manpower is directly a function of the number of tugs flown in the mission model. The effect of a 2 year IOC delay is presented in Figure 11.3.8-5 through 11.3.8-8. Clearly this shortens the operational lifetime and reduces the total manpower expenditure. However, on a year to year basis there is no measureable effect.

TOTAL MANPOWER REQUIREMENTS
CONFIGURATION 3I

	YEAR																					
	80		81		82		83		84		85		86		87		88		89		90	
	SHIFT																					
WTR	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
a							4	4														
b							9	9														
c							5	5														
d							11	5														
e							3	1														
f							2	1														
g							17	15														
1ST SHIFT							51															
2ND SHIFT								40														
TOTAL							91															

a. PROPULSION TECH.
b. MECH./STR./THERM. TECH.
c. AVIONICS TECH.
d. ENGINEERING
e. QUALITY CONTROL
f. SAFETY
g. OTHER

TOTAL MANPOWER REQUIREMENTS
CONFIGURATION 3I

	YEAR																					
	80		81		82		83		84		85		86		87		88		89		90	
	SHIFT																					
ETR	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
a	3	3	6	6	6	6	6	6														
b	9	9	18	9	18	9	18	9														
c	5	5	10	7	10	7	10	7														
d	9	0	22	11	22	11	22	11														
e	3	0	6	5	6	5	6	5														
f	2	0	4	2	4	2	4	2														
g	20	7	42	22	42	22	42	22														
1ST SHIFT	51		108		108		108															
2ND SHIFT		34		62		62		62														
TOTAL	85		170		170		170															

a. PROPULSION TECH.
b. MECH./STR./THERM. TECH.
c. AVIONICS TECH.
d. ENGINEERING
e. QUALITY CONTROL
f. SAFETY
g. OTHER

TOTAL MANPOWER REQUIREMENTS
CONFIGURATION 3F

	YEAR																					
	80		81		82		83		84		85		86		87		88		89		90	
	SHIFT																					
ETR	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
a									12	8	12	8	12	8	12	8	12	8	12	8	12	8
b									15	10	14	10	14	10	14	10	14	10	14	10	14	10
c									18	12	14	12	14	12	14	12	14	12	14	12	14	12
d									45	30	30	30	30	30	30	30	30	30	30	30	30	30
e									10	6	10	6	10	6	10	6	10	6	10	6	10	6
f									6	4	4	4	4	4	4	4	4	4	4	4	4	4
g									59	38	54	37	54	37	54	37	54	37	54	37	54	37
1ST SHIFT									165		138		138		138		138		138		138	
2ND SHIFT										108		107		107		107		107		107		107
TOTAL									273		245		245		245		245		245		245	

a. PROPULSION TECH.
b. MECH./STR./THERM. TECH.
c. AVIONICS TECH.
d. ENGINEERING
e. QUALITY CONTROL
f. SAFETY
g. OTHER

TOTAL MANPOWER REQUIREMENTS
CONFIGURATION 3F

WTR	80		81		82		83		84		85		86		87		88		89		90	
SHIFT	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
a									4	4	4	4	5	4	4	4	4	4	5	4	4	4
b									6	6	6	6	10	6	6	6	6	6	10	6	6	6
c									6	6	6	6	8	6	6	6	6	6	8	6	6	6
d									15	0	15	7	15	15	15	7	15	0	15	15	15	0
e									3	0	3	1	5	3	3	1	3	0	5	3	3	0
f									2	0	2	1	3	2	2	1	2	0	3	2	2	0
g									22	16	22	18	29	22	22	18	22	16	29	22	22	16
1ST SHIFT									58		58		75		58		58		75		58	
2ND SHIFT										32		43		58		43		32		58		32
TOTAL									90		101		133		101		90		133		90	

a. PROPULSION TECH.
b. MECH./STR./THERM. TECH.
c. AVIONICS TECH.
d. ENGINEERING
e. QUALITY CONTROL
f. SAFETY
g. OTHER

TOTAL MANPOWER REQUIREMENTS
CONFIGURATION 3F (2YR IOC DELAY)

ETR	80		81		82		83		84		85		86		87		88		89		90	
SHIFT	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
a									12	8	12	8	12	8	12	8	12	8	12	8	12	8
b									15	10	14	10	14	10	14	10	14	10	14	10	14	10
c									18	12	14	12	14	12	14	12	14	12	14	12	14	12
d									45	30	30	30	30	30	30	30	30	30	30	30	30	30
e									10	6	10	6	10	6	10	6	10	6	10	6	10	6
f									6	4	4	4	4	4	4	4	4	4	4	4	4	4
g									59	37	54	37	54	37	54	37	54	37	54	37	54	37
1ST SHIFT									165		138		138		138		138		138		138	
2ND SHIFT										107		107		107		107		107		107		107
TOTAL									272		245		245		245		245		245		245	

a. PROPULSION TECH.
b. MECH./STR./THERM. TECH.
c. AVIONICS TECH.
d. ENGINEERING
e. QUALITY CONTROL
f. SAFETY
g. OTHER

FIGURE 11.3.8-5

TOTAL MANPOWER REQUIREMENTS

CONFIGURATION 3I (2YR IOC DELAY)

	YEAR																					
	80		81		82		83		84		85		86		87		88		89		90	
	SHIFT																					
WTR	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
a							3	3														
b							9	9														
c							5	5														
d							9	0														
e							3	0														
f							2	0														
g							20	7														
1ST SHIFT							53															
2ND SHIFT								34														
TOTAL							87															

a. PROPULSION TECH.
b. MECH./STR./THERM. TECH.
c. AVIONICS TECH.
d. ENGINEERING
e. QUALITY CONTROL
f. SAFETY
g. OTHER

FIGURE 11.3.8-6

TOTAL MANPOWER REQUIREMENTS
CONFIGURATION 3I (2 YR IOC DELAY)

ETR	YEAR 80 SHIFT 1	80 / 2	81 / 1	81 / 2	82 / 1	82 / 2	83 / 1	83 / 2	84 / 1	84 / 2	85 / 1	85 / 2	86 / 1	86 / 2	87 / 1	87 / 2	88 / 1	88 / 2	89 / 1	89 / 2	90 / 1	90 / 2
a					6	6	6	6														
b					18	9	18	9														
c					10	7	10	7														
d					22	11	22	11														
e					6	5	6	5														
f					4	2	4	2														
g					42	22	42	22														
1ST SHIFT					108		108															
2ND SHIFT						62		62														
TOTAL					170		170															

a. PROPULSION TECH.
b. MECH./STR./THERM. TECH.
c. AVIONICS TECH.
d. ENGINEERING
e. QUALITY CONTROL
f. SAFETY
g. OTHER

FIGURE 11.3.8-7

TOTAL MANPOWER REQUIREMENTS

CONFIGURATION 3F (2 YEAR IOC DELAY)

	YEAR																					
	80		81		82		83		84		85		86		87		88		89		90	
	SHIFT																					
WTR	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
a							4	4	4	4	4	4	6	4	4	4	4	4	6	4	4	4
b							5	5	5	5	5	5	7	5	5	5	5	5	7	5	5	5
c							6	6	6	6	6	6	7	6	6	6	6	6	7	6	6	6
d							15	0	15	0	15	7	15	15	15	7	15	0	15	15	15	0
e							3	0	3	0	3	1	5	3	3	1	3	0	5	3	3	0
f							2	0	2	0	2	1	2	2	2	1	2	0	2	2	2	0
g							19	14	19	14	19	16	27	19	19	16	19	14	27	19	19	14
1ST SHIFT							54		54		54		69		54		54		69		54	
2ND SHIFT								29		29		40		54		40		29		54		29
TOTAL							83		83		94		123		94		83		123		83	

a. PROPULSION TECH.
b. MECH./STR./THERM. TECH.
c. AVIONICS TECH.
d. ENGINEERING
e. QUALITY CONTROL
f. SAFETY
g. OTHER

FIGURE 11.3.8-8

11.4 Logistics

The MDAC Space Tug Logistics Concept incorporates the Spares, Transportation and Handling, Training and Inventory Control and Warehousing functions.

Spares

The maintainability analyses have addressed unscheduled maintenance in terms of spares requirements. This applies risk of failure analysis methods to prediction of spares requirements and maintenance manhours. The results of the analyses are summarized herein. It will be noted that several candidate configurations have the same predicted performance although there are differences in subsystem equipment. This results from several considerations. These include the gross state of descriptions that do not permit differentiation in parts counts or complexity of some components; all engines are considered to require the same unscheduled maintenance although there are differences in scheduled maintenance; and rounding off at a reasonable decimal value. All predictions were made by the same methods, thus assuring that the data presents the proper range of relative performance for purposes of preferential evaluation and ranking with regard to unscheduled maintenance.

Spare parts costs estimates were introduced into the cost model in terms of initial spares and depot maintenance, measured in terms of equivalent units of production subsystem hardware costs. The initial spares support repair of any failure present in a returning Tug for the first five flights. The estimates for subsystems assumed at least one of each replaceable item plus several additional parts for those items having a high failure risk and a long flow for depot overhaul. The initial stock is a function of flight frequency, depot flow time and desired probability of sufficient stock for any contingency. Depot maintenance costs are based on failure rate, estimated repair level (percent of component replaced) and percent of part cost to handle the cost of the repair cycle. An example of the method of calculation is provided in Appendix C.

Transportation and Handling

This function considers the following areas of hardware movement:

- o Intrafacility operations at MDAC during manufacturing and refurbishment
- o Delivery of new Tugs to KSC and WTR
- o Rotable spares between launch sites and factory/depot area
- o Switching of individual Tugs between KSC and WTR
- o Intrafacility operations at KSC and WTR
- o KSC/WTR to and from Shuttle alternate landing site

The primary mode of transportation between MDAC and KSC/WTR will be by "Guppy" type aircraft when delivering new Tugs or when switching operational Tugs between KSC and WTR. Movement of Tug hardware (other than a complete Tug) will be accomplished via appropriate land and air modes as dictated by specific program requirements.

The selection of preservation methods, packaging levels, and protective handling shall be based on analysis of natural and induced environments to which the hardware will be subjected during its life cycle. Major emphasis shall be placed on minimizing damage from environmental hazards encountered during storage, handling and transportation. Special attention shall be given to parts procedures to insure that program critical hardware items are given preferential treatment throughout the manufacturing and logistics pipeline. Selection of preservation methods, packaging design, and level of protection shall provide a reasonable balance between cost and performance.

Training

The training concept for the Tug Program is based on the premise that training will be required for all ground personnel (customer and contractor) and that personnel assigned to the Tug Program will already be skilled in their respective specialties; therefore, training requirements will be limited to the adaptation of their respective skills to Tug hardware and ground operations.

Training will be conducted at the manufacturer's location and at KSC and WTR. There will be no requirement for simulators and dedicated training equipment. Test and flight hardware, augmented by audio/visual aids will be used. No special training facilities requirements are planned.

Inventory Control and Warehousing

The material control function includes the receiving, shipping, issue, repair, inventory control and storage of spares, repair parts, and special test equipment (Contractor Furnished Equipment [CFE] and Government Furnished Equipment [GFE]) located at either the MDAC manufacturing facility or at the KSC/WTR launch sites. The MDAC concept considers the contractor and user's responsibilities from acquisition through the operational phase for property control and accountability of CFE and GFE being utilized to support the program. The contractor shall be responsible for controlling stock levels, issues, and maintaining inventory and property records of all material. The contractor shall maintain such records on GFE for the purpose of receipt control by requisition number and contract number. The contractor shall perform follow-up action in accordance with customer requirements. GFE spare end items furnished for the Contractor's Program shall not be co-mingled with GFE furnished for production installation. Progressively, usage data shall be compiled during the Contractor Support Program for systematic and timely support review to determine future procurement and stock replenishment. Accurate reporting of transactions and end use of hardware is the most important aspect of usage data.

CFE and GFE shall be stored under bonded warehouse concept, utilizing good housekeeping practices. Special emphasis is placed on control, security, and protection of material. Items furnished for support of this program shall not be co-mingled in storage with items of any other program, contract, or project. Items shall be stored in an arrangement that will facilitate stock control and inventory. The Armed Service Procurement Regulations (ASPR) and NASA Procurement Regulations contain the basic requirements for management and control of GFE in possession of a contractor. MDAC will handle CFE in the same manner prescribed for GFE and will assure that its subcontractors handle GFE on this program in accordance with the aforementioned government requirements.

MDAC, together with NASA/DOD will schedule two transition conferences; a planning conference and a final conference. At these conferences, the NASA/DOD and MDAC will review and evaluate the experience encountered throughout the Contractor Support Program, determine and initiate action to satisfy any deficiencies, and provide for an orderly transfer of assets to the government or operational contractor.

11.4.1 Spares

The spares planning analysis has developed a spares list to level 8 and a subsystem overhaul cost. The detail data are presented in Appendix C along with a description of the calculation methods used. The Tug maintainability analysis process is illustrated in Figure 11.4-1.

The spares planning data are primarily directed at developing a viable life cycle cost prediction. The list of potential spares was developed for two levels. The subsystems were analyzed to establish a repair policy that would be possible with the expected support equipment and test facilities. The repair policy provided a list of line replaceable units (LRUs) for Tug repair and refurbishment. These LRUs were in turn subdivided into subassemblies to provide a parts list to level 8. Reliability failure rates were allocated to the subassembly level and component and subassembly expected failures were calculated using flight time plus expected preflight ground operation time. An additional anomaly multiplication factor was applied to represent the number of items that may need to be changed or adjusted for each failure that actually occurs in a completely checked out, flight ready, system.

The expected failures value provided the basis for calculating spares and overhaul support. Poisson tables were used to determine quantities of initial and operational spares. Initial spares were selected in a quantity to provide an 0.90 probability of no LRU stock depletion for 5 flights. Operational spares were selected to assure at least one subassembly for repair of the LRU and additional quantitites as required to assure an 0.995 probability of sufficient stock to repair and refurbish LRUs with a level II maintenance flow rate based on 5 flights.

Depot spares estimates are based on equivalent subsystems required as a bottom up prediction, whose individual item depot costs are based on a 30% refurbishment cost for the expected failures for the total number of Tug missions.

The mathematics for the calculations are shown in Appendix C.

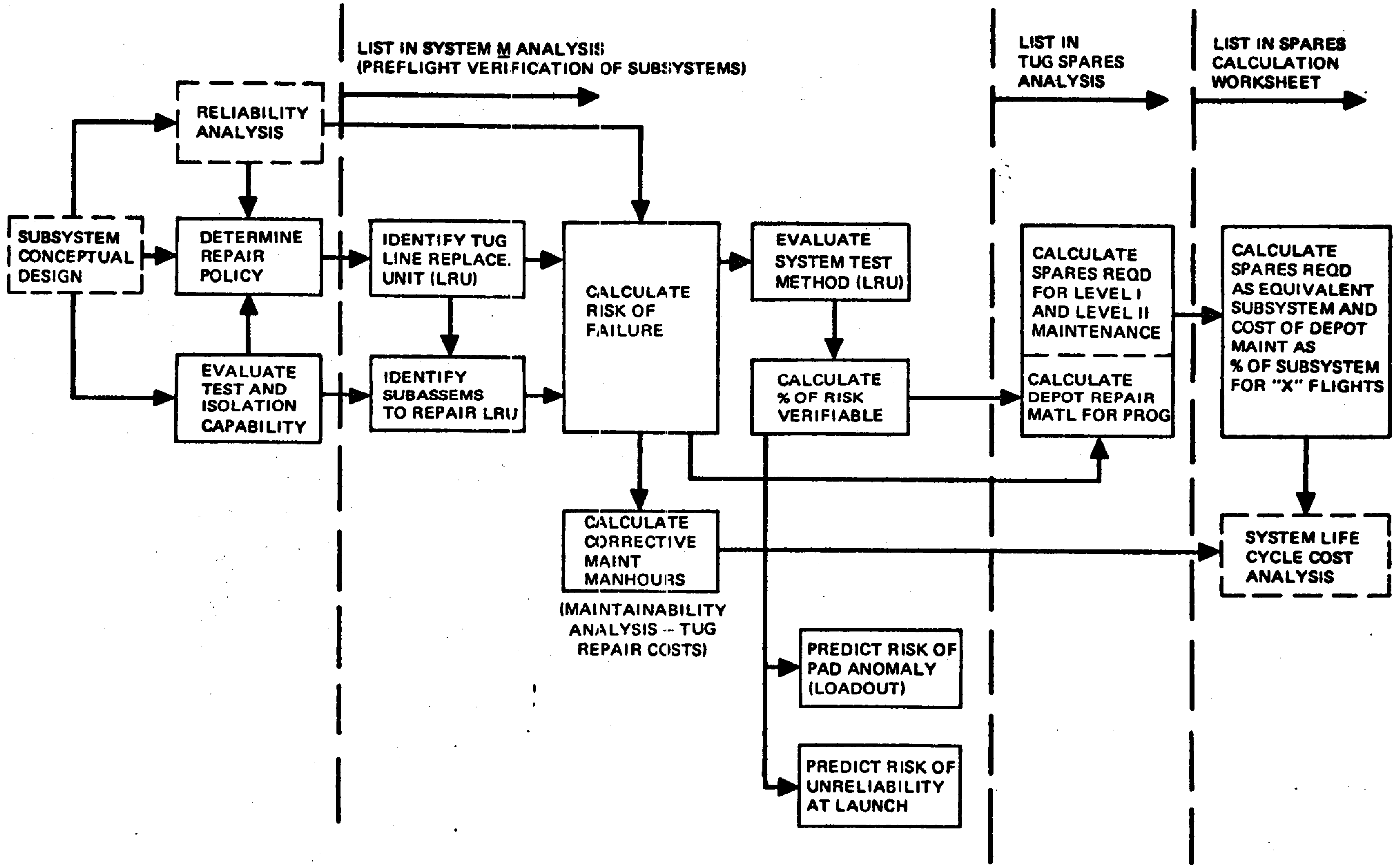


Figure 11.4. Tug Maintainability (M) Analysis Process

11.4.2 Training

Introduction. A comprehensive training program on the Tug subsystem and its associated support equipment will be provided to assure the availability of trained and qualified personnel required to produce, assemble, check out and deliver the tug and its associated support equipment and to support the test and operational flights.

During the Saturn S-IVB and OWS programs, MDAC participated in a comprehensive task-oriented classroom training program; making maximum use of engineering mockup, models, and simulation devices to develop and maintain personnel skills. Each course was tailored to meet specific NASA requirements and stressed man-rating and safety. These programs proved extremely successful as evidenced by these programs' achievements. The same policies and criteria will be utilized in the development of the Tug training program.

Training services for NASA, DOD & MDAC employes (technicians, engineers, inspectors, test flight personnel, etc.) will be provided by a centralized training group. This group will be staffed with experienced system training instructors organized and managed to meet NASA, DOD and contractor employe training requirements. These instructors participate in the development of training requirements, development of System Training Plan, and conduct training.

Objectives. The objectives of the Tug Training Program are: (1) Identify and develop training requirements for courses in a timely manner to permit the orderly development and implementation of training; (2) Develop and implement training courses to ensure the availability of qualified personnel and skills required for the performance of assigned tasks; (3) Provide quantitative and qualitative needs for trained personnel that satisfy program schedule requirements; and (4) Provide training services for customer and contractor personnel in support of their Tug system requirements.

Approach. Training services for NASA, DOD, MDAC employes (technicians, inspectors, test engineers, etc.) and flight support personnel shall be provided by a centralized training function. Cost control objectives shall be achieved by use of innovative training concepts developed for otherNASA and military training programs as follows:

- Centralized training management permitting instructor participation during the Training Requirements Analysis. Development of the Training Plan and the dual utilization of instructor for the conduct of both customer and employe training programs, being responsive to schedule requirements of both.
- Making maximum use of engineering development mockups, models and test and flight articles for training; thus eliminating the development and production costs of special training devices.
- Identify the appropriate Audio Visual Media for application to classroom, OJT, and follow-up training as the system is developed.
- Maintain a current catalog of Employe Training courses, complete with schedules, permitting the customer to participate as desired.

Program quality, quality of personnel, and cost objectives will be achieved by the implementation of these concepts. The planning and control function is a key element for the smooth integration of NASA, DOD and MDAC Tug System Training Requirements

Training Requirements. Training Requirements Analysis for customer and MDAC personnel will be concurrent with the Design, Development and Production Planning. The analysis encompasses all areas of job/tasks function, i.e., production skills, quality assurance, test engineers, inspectors, etc., and is conducted in the following steps; population group identification, job/task definition, and the identification of technical material required for use by each population group. The analysis determines the requirements for both classroom and other types of instruction for personnel. All MDAC training records will be processed and maintained. Figure 11.4.2-1 illustrates the interrelationships, identifies the products and services provided, and the sequence of development and implementation. Special training requirements imposed by the customer are are developed, scheduled and conducted in the same manner as for MDAC personnel. Table 11.4.2-1 lists Tug training categories that are applicable for NASA and DOD personnel.

Table 11.4.2-1

NASA/DOD Training Courses

Type of Course	Description	Population Groups
Briefings	Introduction to the Tug program to include ground equipment. Serves as an introduction to individual systems briefings and more detailed instruction.	NASA & DOD management personnel & program planners
Familiarization	Introduction to the Tug program including ground equipment identification and description of subsystems, major units and functions.	Technical supervision & flight personnel
Subsystems, Design	Detail analysis of design requirements, functional and operational. Parameter of subsystem and its supporting ground equipment.	Project System Engineering, Ops engineering, launch support

MDAC training requirements analyses are concurrent with the development of Systems Requirements and Support Requirements.

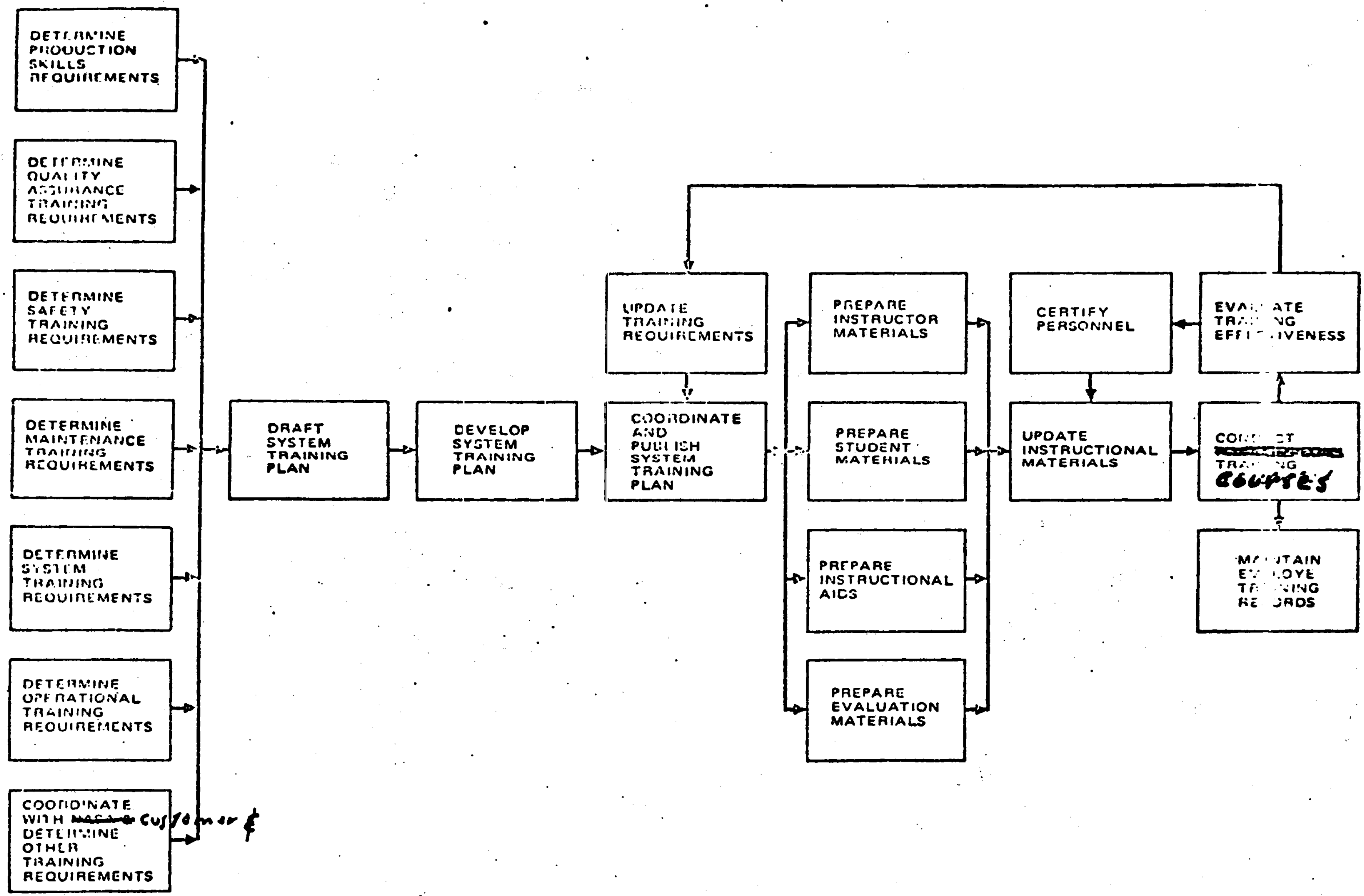


Figure 11.4.2-1. Training Products and Services

Student population groups are identified, job/task definitions developed, skill levels determined to accomplish task and the identification of technical materials required for use of each population group. The analysis determines the requirements for both classroom and other methods of instruction for MDAC personnel. Table 11.4.2-2 identifies employee population groups requiring training and a brief description of the type of instructions provided.

Table 11.4.2-2

Development & Production Training Programs/Courses

Employe Population Groups	Description
Safety	Identification of hazards and potential hazards to personnel and equipment, and methods of accident prevention.
Inspection and non-destructive testing	Work-oriented instruction on techniques and procedures on testing, inspection, and operation of specialized equipment for quality assurance personnel.
System and support equipment	All levels of instruction describing theory and function of operational end items, systems, subsystems, and support equipment.
Transportation and handling	Describe operation of equipment--both static and mobile--used to handle, transport or position hardware.
Maintenance	Detailed task-oriented instruction in maintenance, servicing, overhaul, and repair of equipment.
Material processes	Skill development in critical manufacturing process, i.e., metals, chemicals, bending, compounds, welding, etc.
Assembly processes	Skill development in critical manufacturing process, i.e., metals, chemicals, bending, compounds, welding, etc.
Test equipment operation	Task-oriented instruction on operation and application of standard and special test equipment.

The result of the training requirements analysis is documented and included in the training plan. The updating of the requirements is continuous and incorporated into each revision of the Training Plan.

Tug System Training Plan. Development of a Tug System Training Plan shall be initiated at ATP and be concurrent with the Training Requirements Analysis. The Training Requirements Analysis is the basis for identifying courses to be conducted for NASA, DOD, and MDAC employes. The plan identifies methods and procedures for each course, course objectives, and identifies equipment required to support the course; it includes course outlines, descriptions, manpower requirements, evaluation criteria and contains a schedule for each course identifying the location of presentation so customer personnel may participate, as desired. This curriculum includes general purpose courses to provide personnel with brief general descriptions and functions of the Tug system, plus job-oriented courses for student population groups identified in the Training Requirements Analysis. The plan ~~shall identify any special courses for customer personnel~~ required for a smooth transition from DDT&E to Operations. The training plan is a working document for training implementation and becomes the framework for annual planning of training operations. Adjustments are made to the plan as program requirements are altered, and an annual updated submittal shall be made through the first manned orbital flight.

Production Skills Training. Processes involving vocational skills training are identified in the Detail Process Standards (DPS) or Detail Process Instructions (DPI) prepared by Material Methods and Research Engineering (MM&RE), and training is conducted in accordance with these instructions. Upon completion of vocational skills courses, students are required to demonstrate skill proficiency by manual and written examinations, and are certified as required by QA. Apprenticeship and/or learner programs, where applicable, are developed, conducted and administered by Training in accordance with Federal and State regulations.

Quality Assurance Training. Courses designed for Quality Assurance personnel stress the inspection techniques and quality requirements in addition to manipulative or manual skills. Quality control is an integral part of all skills training programs. The contribution of each individual's work to the success of the program is constantly emphasized.

Safety Training. Personnel and system safety is stressed in all training courses. The Safety Department and/or the Safety Manual may indicate areas for special concentration. These special safety training programs are established and conducted for identified employes or departments after course approval by the Safety Department.

Technical Training. Technical training is accomplished by various methods, conducted by the training organization, performed by experts from the operating department involved (with guidance and assistance from the Training Department), or programmed with self-taught instructional media. Whatever methods used are coordinated and approved by the Training Department prior to the conducting of the course.

Technical orientation is initiated early in the program to orient newly assigned personnel on the Tug Program, provides a general description of the Tug system, system function, and Shuttle interface information, and is planned to be approximately four classroom hours. The technical content will be maintained at a level consistent with the instructional objective of providing management, and newly assigned personnel, with a brief but comprehensive overview of the Tug Program .

Familiarization training courses are developed for presentation to Engineering, Technical, Manufacturing, Checkout, and Quality Assurance personnel as soon as desigh concepts are established to provide thorough familiarity with all aspects of the Tug system, supporting equipment and operation. The technical content will be maintained at a level consistent with the instructional objective of providing technical personnel with a working knowledge of the Tug and its supporting equipment, and is planned for approximately eighteen classroom hours.

The identification and depth of maintenance training courses result from Support Requirements ANalysis (SRA). The results of the SRA will culminate in the identification of maintenance training requirements, and courses will be designed to support all levels of maintenance. Instruction in detailed system operation, trouble-shooting and repair techniques provide the skills required to meet scheduled turn-around requirements, cost, and loading effect on equipment and facilities. Course outlines and descriptions will be developed and documented in the Training Plan.

MDAC personnel involved in test flight operations are provided detailed instructions on the Tug system and its support equipment in terms of trouble-shooting, on-line repair, test and launch operations. The level of instruction provided is identified in the Training Requirements Analysis and documented in the training plan. Special course are developed and documented for technical personnel, and the implementation is consistent with the program schedule. NASA, DOD and Launch contractor personnel are invited to attend these courses to partially fulfill the operational training requirement for transition to the operational phase.

The initial cadre of personnel for the operational phase will participate in test flight training, test flight launches, and be prepared to support the operational launches. Additional launch teams assigned to meet the projected launch schedule will receive the same instruction as flight test personnel, and all crews will require refresher training periodically to maintain their launch capability and proficiency.

Maximum use of engineering mockups, models, etc. shall be made to enhance the instructional program for the development and maintenance of personal skills required to assemble, check out, test and launch the Tug system. Instructional devices are production hardware, wherever practical, and rejected parts, components or test items are utilized when they do not detract from the training objectives.

Tools and machines required for vocational training are the same as used in production areas, and applicable training will be accomplished on equipment in the production area, where possible. Documentation of vocational training courses will be accomplished in accordance with established standards.

<u>Instructional Documentation</u>. The Tug system documentation is utilized for task-oriented instructions when it is determined to be suitable for instructional purposes. When system documentation is not suitable or available for instruction, special training documentation shall be developed, such as operational and functional diagrams, descriptions and interface information.

The preparation of Tug training manuals is initiated at system PDR, making maximum use for existing documentation, and includes system and subsystem descriptions, functional diagrams and visuals to enhance the learning process. The manuals are prepared, published and used to fulfill the training requirements of operational training and are turned over to the customer at the completion of test flight operations.

Instructional Media. Instructional media used varies according to the subject and training objectives. Basic technique used is oral presentation, demonstration, application, examination, review and/or critique. Instruction is supported by video tape, overhead transparencies, slides and movies.

As a supplement to the tri-level Tug classroom training,

video tape presentations and demonstrations will be developed for tasks and subjects where such supplement is indicated by the training requirements analysis. Video tape is particularly effective as an instructional aid in bringing the production areas into the classroom for vocational skills training.

Video casettes, chosen for ease of operation consistent with high image quality, will be produced by MDAC personnel experienced in telecommunications production on the Safeguard and Skylab programs. These video casettes can be easily updated to include program or design changes, and will provide readily accessible refresher material for NASA, DOD and launch contractor personnel after initial training.

Training Program Implementation. The basic method of instruction shall be the traditional standup technique of classroom instruction using charts, transparencies, chalkboard, etc., and augmented by special audio-visual techniques when they enhance the training or are cost-effective.

Tri-Level Training Concept. A tri-level approach is planned for implementing the Tug training program. This approach enables each employe to receive only that instruction relevant to his job assignment. This approach reduces the number of student classroom hours by not subjecting him to "nice-to-know" but irrelevant information. MDAC shall conduct all courses using the tri-level approach. Figure 11.4.2-2 illustrates this concept, and a brief description of each level of presentation is provided in the following paragraphs.

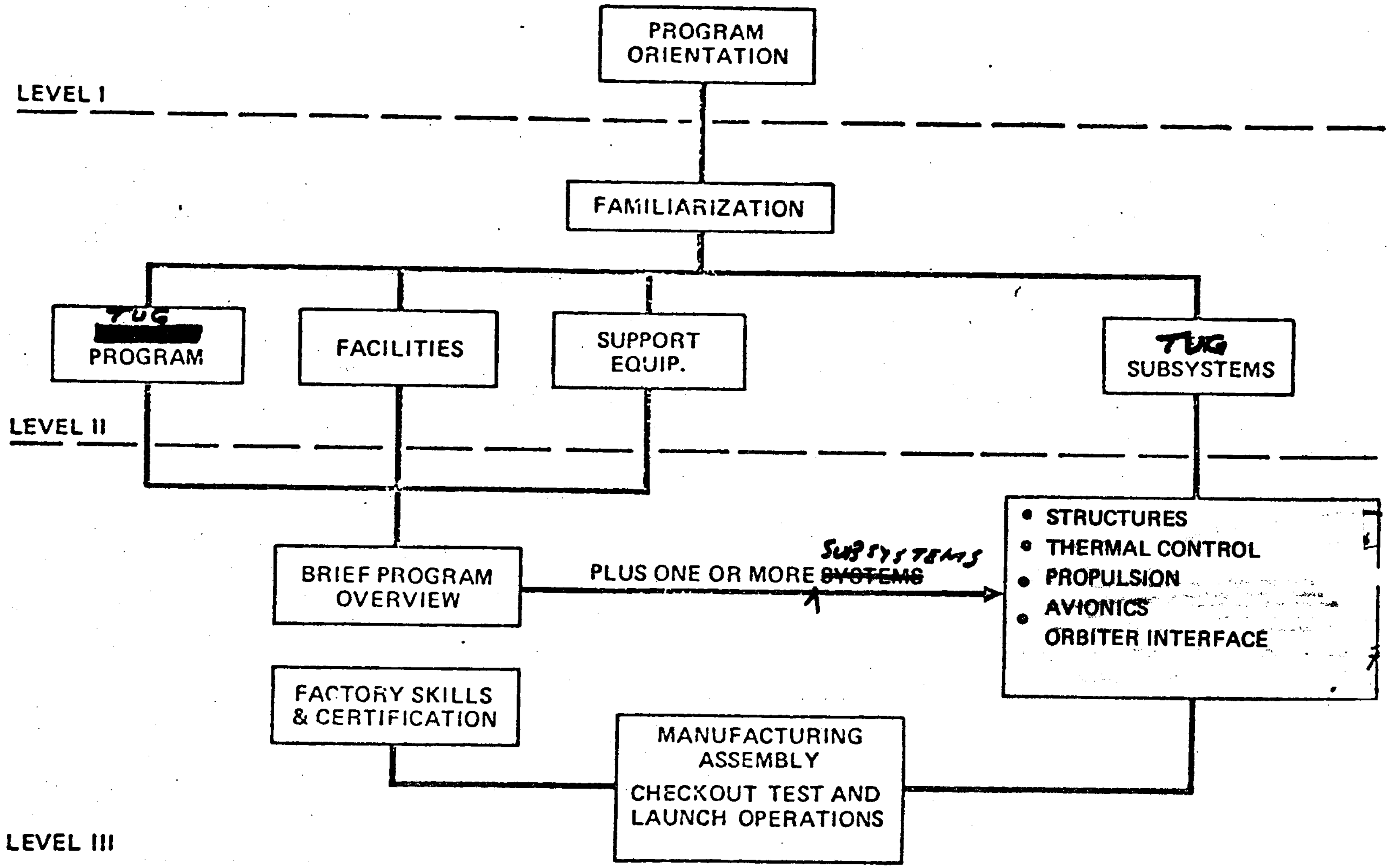


Figure 11.4.2-2. Training Levels

Level One - Orientation. The orientation courses will introduce the Shuttle Program, the Tug vehicle and its associated support equipment to all program personnel as they are assigned, and provide them with general descriptions and functions of the systems to be utilized on the Tug program. Technical content of the course will be maintained at a level consistent with the objective of providing management, planners, and newly assigned personnel with a comprehensive but brief overview of the Tug program.

Level Two - Familiarization. Familiarization courses provide a brief overview of the Shuttle program, and expand upon the Tug system, system support equipment, manufacturing and checkout operations, culminating in factory checkout, assembly and test flight operations. These courses are the basis upon which specialized training for particular task areas are founded.

Level Three - Specialized. These courses will be designed to provide a brief overview of the Tug Program and detailed theory, operations, and maintenance functions associated with specialized tasks on the Tug vehicle. support equipment, assembly, test and launch.

Summary. MDAC is responsive to the Tug Program requirements by providing a training staff of experienced training specialists to participate in the definition of Tug system training requirements, developing a training plan, and conducting training. The preparation and conduction of training shall be time-phased to provide qualified personnel, economically managed to control program cost, and flexible enough to meet all program requirements. A representative manpower build-up is shown in Figure 11.4.2-3 AND 11.4.2-4

Type of Effort	ATP 75	76	77	78	IOC 79	80	81	82	83	84	85	86	87	88	89	90	Total
Program Planning		1	1	1	1	1											5
Training Reqmts & Plan		1	1	1	1	1	1	1	1	1	1	1	1	1	1		14
Course Preparation			2	2	2												6
Instructional Documentation			1	2	3	3	2										11
Instructors				3	10	10	10	8	3	3	2	2	2	2	1		56
Total		2	5	9	17	15	13	9	4	4	3	3	3	3	2		92

Note
Build-up value shown in man years

Program 3I

TRAINING BUILD-UP

Figure 11.4.2-3

Type of Effort	75	76	77	78	ATP 79	80	81	82	IOC 83	84	85	86	87	88	89	90	Total
Program Planning						1	1	1									3
Training Reqmts & Plan							1	1	1	1	1						5
Course Preparation							1	2	2								5
Instructional Documentation								1	2	1	1						5
Instructors								2	5	5	4	3	3	2	2	2	28
Total						1	3	7	10	7	6	3	3	2	2	2	46

Note

1. Build-up values shown in man years
2. Reduced training build-up results from 50% commonality of 3I with 3F.

TRAINING BUILD-UP

Program 3F

Figure 11.4.2-4

11.4.3 Transportation and Handling

Introduction

The Spare Tug, its subsystems assemblies and components will be moved a considerable number of times during their program life by a variety of transportation and handling vehicles and equipment. During these movements, the Tug vehicles/equipments are subjected to stresses and loads which may vary from those experienced in a mission environment. The Tug design criteria will be based on flight loads; therefore the transportation and handling loads must be predicted during design and, where necessary, reduced to assure that structural damage does not occur during Tug transportation and after ground operations. The methods and procedure necessary for protection of the Tug hardware elements during vehicle assembly, testing, transportation and storage are developed as a result of the transportability/transportation analyses.

The selection of preservation methods, packaging levels, and protective handling will be based on analysis of natural and induced environments to which the hardware will be subjected during its life cycle. Major emphasis shall be placed on minimizing damage from environmental hazards encountered during storage, handling and transportation. Special attention shall be given to parts protection procedures MDAC will follow to ensure that program critical hardware items are given preferential treatment throughout the manufacturing and logistics pipeline.

Policy

As a matter of policy, transportation and handling planning will incorporate the following guidelines and assumptions:

a. Use of existing, rather than design of new transportation and handling equipment, where practical.

b. Early identification of any Tug Program peculiar transportability constraints.

c. Maximum utilization of state-of-the-art packaging materials, methods, and designs, where practical.

d. Special protective measures for Program critical hardware.

e. Implementation of integrated packaging, handling, and transportation functions outlined in MSFC-STD-343 to the maximum extent possible within cost effective guidelines.

f. Preferential consideration of air transportation, but use of other modes where more effective or practical.

g. Appropriate safety provisions for dangerous or hazardous materials.

Transportability

Some of the Tug Program items (assemblies, subassemblies, GSE and spares may be oversize environmental sensitive or hazardous relevant to normal transportation modes. Therefore, a transportability analyses shall be performed to ensure that the Tug vehicle hardware, GSE and their shipping containers/fixtures are designed for efficient transportation. Transportability analyses are provided to define hardware constraints required to select transport and handling equipment and primary and alternate modes of transportation. The basic tasks that are accomplished in the transportability engineering Process are as follows:

a. Identify potential transportability problem areas and define the nature of the constraints (oversize, environmentally sensitive or dangerous).

b. Perform transportability analyses to determine transportation impact on hardware design and preferred methods for transporting problem items.

c. Prepare transportability reports for problem areas. The reports will provide the following data:

   1. Detailed characteristics of problem items (size, weight, C.G. environmental sensitivity, hazardous, etc.)

   2. Special packaging, handling and transportation requirements.

   3. Handling, loading and tie-down methods and configuration for proposed transportation methods.

d. Develop transportation data for special items (as required).

e. Investigate capabilities and limitations of available equipment and service of the candidate modes of transportation at origin and destination.

f. Evaluate transport limitations at manufacturing, assembly, and test sites.

g. Investigate existing handling and transportation equipment inventories for possible use on the Tug Program.

h. Provide handling and transportation procedures and instructions defining methods of loading, off-loading, securing and handling problem items for shipment.

i. Provide transportability inputs to system and equipment specifications.

j. Define the natural and induced environments that hardware will encounter.

k. Develop transportation and storage requirements for hardware in logistics pipeline.

l. Develop requirements criteria for the design of special transportation equipment.

m. Conduct transportation tests for oversize items container designs, as required.

n. Provide transportability engineering support to program for shipment and receipt of test items and mockups.

o. Establish interface with Design Engineering early in Program to minimize transportability constraints.

Transportation and Handling

An overall transportation plan, including packaging, handling, transportability, transportation and storage, shall be developed and implemented as a part of the total system approach for the movement and storage of Tug hardware. The purpose of the plan is as follows:

a. Establish an optimum system for moving materiel, defining the system in such detail that the impact of individual elements on total system cost and performance can be analyzed.

b. Provide technical requirements and administrative procedures for implementing safe and timely movement of materiel.

c. Provide management with sufficient visibility of the packaging, handling and transportation system to effectively control and manage its implementation.

Transportation tasks which must be accomplished for developing and implementing an effective plan are as follows:

a. Perform feasibility and cost trade-off studies in the areas of packaging, cargo handling, transportation and storage to develop the most cost-effective system for the movement of Tug hardware.

b. Integrate transportability data into transportation planning activities.

c. Provide route surveys for oversize items.

d. Identify the hardware shipments by destination and volume for maximum consolidation.

e. Establish transportation flow patterns for the different hardware categories.

f. Determine most feasible and economical methods for transporting the various categories of material in consonance with program schedules.

g. Identify the shipping documentation used during shipment.

h. Identify unique requirements for special transportation equipment and services for each shipment.

i. Release transportability reports recommending preferred modes for potential problem items.

j. Identify functional responsibilities for implementing the transportation plan.

k. Establish traffic management procedures for obtaining the proper handling and transportion equipment.

l. Provide procedures for obtaining route clearances and overweight/dimensional permits.

m. Establish traffic management procedures for controlling the movement of hardware in transit.

n. Establish procedures for interfacing and coordinating with customer transportation agencies.

o. Define the Department of Transportation, NASA, DOD and other federal. state and local government regulations governing the Tug. packaging, transportation and storage activities.

p. Manage and coordinate all movements of heavy, bulky Tug components with other agencies and supervise vehicle loading/off-loading activities.

Preservation, Packaging and Packing.

A systems approach shall be implemented for performing the activities associated with the protection of Tug Vehicle hardware, spares, GSE, tooling, and test equipment during movement and storage. Centralized control shall be provided to eliminate duplication of tasks and reduce distribution costs. Preservation methods, packaging design, and level of protection will provide reasonable balance between cost and performance. A description of the tasks follow:

a. Direct all activities necessary to develop and coordinate program preservation, packaging, and packing.

b. Develop and design in-plant and intra-plant handling devices and containers.

c. Develop and issue drawings for containers, tie-downs, loading and handling instructions, parts protection, and hazardous material.

d. Prepare "Preparation for Delivery" sections of Specificat Control, Source Control, and Design Procurement drawings.

e. Coordinate packaging, handling, and transportation matters with customer.

f. Develop and maintain Packaging and Preservation sections of Transportation Plan for the Tug Program.

g. Conduct training courses on packaging procedures for field station preservation and packaging personnel.

h. Develop and issue material and process specifications.

i. Interface with Maintainability and Maintenance Analysis for detailed preservation and packaging requirements.

j. Prepare and release in-plant packaging and handling instructions.

k. Monitor subcontractor and vendor packaging activities.

l. Coordinate packaging designs and instructions with engineering and operations personnel.

m. Identify and provide special instructions for handling, shipment, and storage of program critical and hazardous hardware, such as rocket motors. Release Special Protection Items List (SPIL).

n. Analyze environmental hazards encountered in handling, transporting, and storing hardware in logistics pipeline.

o. Develop and design light-weight containers for flight hardware, fly-away kits, and test support equipment.

p. Prepare a Storage Plan defining levels of protection for temporary and long term storage.

q. Prepare and release Special Design Packaging drawings for these items presenting unusual transportation and handling problems.

r. Initiate Packaging, Handling, and Transportation Record (PHTR) for program critical and high cost items.

s. Release instructions for implementing NASA Zero-Damages-on-Delivery (ZDOD) Program.

t. Release special instructions for marking critical and dangerous materials.

u. Develop packaging, handling, and transportation records (PHTR) per MSFC-STD-343.

Transportation Modes, Matrix and Cost Methodology

The two major modes of transportation planned for the Tug Program are (1) air and (2) truck. The air mode will employ Guppy aircraft to transport a complete tug and commercial airfreight or US Air Force Cargo aircraft to transport Tug hardware elements of lesser size than the complete tug. The air mode will be used primarily for long distance movement and the truck/transportation mode will be employed for short distance/local movement requirements. A transportation matrix showing the type of interfacility traffice is shown in Figure 11.4.3-5. The transportation cost methodology is shown in Figure 11.4.3-6 and 7.

FROM \ TO	MDAC HUNTINGTON BCH	KSC	WTR	GFE CONTRACTORS	SUBCONTRACTORS AND SUPPLIERS	TEST SITES
MDAC HUNTINGTON BCH	INTRAFACILITY HANDLING	NEW TUGS	NEW TUGS	MAIN ENGINES AND REPAIRABLE LRUs	REPAIRABLE LRUs	REPAIRED/ REPLACEMENT LRUs
KSC	REPAIRABLE LRUs	INTRAFACILITY HANDLING	OPERATIONAL TUGS	MAIN ENGINES KICK STAGES & REPAIRABLE LRUs	REPAIRABLE LRUs	
WTR	REPAIRABLE LRUs	OPERATIONAL TUGS	INTRAFACILITY HANDLING	MAIN ENGINES, KICK STAGES & REPAIRABLE LRUs	REPAIRABLE LRUs	
GFE CONTRACTORS	MAIN ENGINES AND REPAIRED/ REPLACEMENT LRUs	MAIN ENGINES AND KICK STAGES	MAIN ENGINES AND KICK STAGES	INTRAFACILITY HANDLING		MAIN ENGINES, REPAIRED/ REPLACEMENT LRUs
SUBCONTRACTORS AND SUPPLIERS	REPAIRED/ REPLACEMENT LRUs	REPAIRED/ REPLACEMENT LRUs	REPAIRED/ REPLACEMENT LRUs		INTRAFACILITY HANDLING	REPAIRED/ REPLACEMENT LRUs
TEST SITES	REPAIRABLE LRUs	HANDING EQUIPMENT	HANDLING EQUIPMENT	MAIN ENGINES AND REPAIRABLE LRUs	REPAIRABLE LRUs	INTRAFACILITY HANDLING

Figure 11.4.3-5. Transportation Matrix

8

TRANSPORTATION COST METHODOLOGY

INPUT DATA - PROGRAM OPTION 3I

FLEET SIZE: 5 ETR - 4 WTR - 1

TRAFFIC REQUIREMENT
- INITIAL DELIVERIES
- 1 KSC TUG SWITCHED WITH 1 WTR TUG ONCE EACH YEAR

GUPPY AIRCRAFT ESTIMATED COST PER FLIGHT
- LOS ALAMITOS NAVAL AIR STATION, CALIFORNIA TO KSC =$25K (ONE WAY) AND $50K (ROUND TRIP)
- LOS ALAMITOS NAVAL AIR STATION, CALIFORNIA TO WTR =$5K (ONE WAY) AND $10K (ROUND TRIP)
- WTR TO KSC =$25K (ONE WAY) AND $50K (ROUND TRIP)

COST CALCULATION

4 INITIAL DELIVERIES TO KSC AT $25K/TRIP	100K
1 INITIAL DELIVERIES TO WTR AT $5K/TRIP	5K
3 KSC TUGS TRANSFERRED TO WTR AT $25K/TRIP	75K
3 WTR TUGS TRANSFERRED TO KSC AT $25K/TRIP	75K
TOTAL	$ 255K

NOTE:
1. LRU TRANSPORTATION COSTS INCLUDED IN DEPOT MAINTENANCE COSTS
2. INTRAFACILITY HANDLING COSTS INCLUDED IN FACTORY/DEPOT AND LAUNCH SITE OPERATING OVERHEAD

Figure 11.4.3-6

TRANSPORTATION COST METHODOLOGY

INPUT DATA - PROGRAM OPTION 3F

FLEET SIZE: 9 ETR - 8 WTR - 1

TRAFFIC REQUIREMENT

INITIAL DELIVERIES

1 KSC TUG SWITCHED WITH 1 WTR TUG ONCE EACH YEAR

GUPPY AIRCRAFT ESTIMATED COST PER FLIGHT

LOS ALAMITOS NAVAL AIR STATION, CALIFORNIA TO KSC =$25K (ONE WAY) AND $50K (ROUND TRIP)

LOS ALAMITOS NAVAL AIR STATION, CALIFORNIA TO WTR =$5K (ONE WAY) AND $10K (ROUND TRIP)

WTR TO KSC =$25K (ONE WAY) AND $50K (ROUND TRIP)

COST CALCULATION

8 INITIAL DELIVERIES TO KSC AT $25K/TRIP	200K
1 INITIAL DELIVERIES TO WTR AT $5K/TRIP	5K
4 KSC TUGS TRANSFERRED TO WTR AT $25K/TRIP	100K
4 WTR TUGS TRANSFERRED TO KSC AT $25K/TRIP	100K
TOTAL	$ 405K

NOTE: 1. LRU TRANSPORTATION COSTS INCLUDED IN DEPOT MAINTENANCE COSTS
2. INTRAFACILITY HANDLING COSTS INCLUDED IN FACTORY/DEPOT AND LAUNCH SITE OPERATING OVERHEAD

Figure 11.4.3-7

11.5 Facilities

This section describes the manufacturing and test operations and Tug processing facility requirementts with cost data used in trades.

6.11.5.1 Manufacturing and Test

Manufacture and checkout of the Space Tug will be accomplished at the McDonnell Douglas Astronautics Company, Huntington Beach, California, facility.

The Huntington Beach facility was planned and designed from inception to provide fully integrated facility capabilities for space vehicles. Its buildings consist of engineering and administration offices, a Systems Integration Laboratory, Structural Test Laboratory, Space Simulation Laboratory, Production Test Laboratory, Manufacturing and Assembly Building, Insulation Building, Final Assembly and Checkout Building, and other service and support buildings.

Maximum utilization will be made of the existing MDAC and government owned facilities used on the Saturn SIVB Orbital Workshop and other programs in the development and production of the Space Tug. This will include but not be limited to such MDAC facilities as the existing machine shops, sheet metal shops, process shops, electrical/electronic fabrication and assembly, and supporting inspection and test laboratories.

A preliminary list of additional facility requirements identified at this time, for each of the configurations are shown in Table 11.5.1-1 along with ROM cost and procurement lead time estimates.

Production testing (and checkout) will be done at Huntington Beach in existing laboratories of the McDonnell Douglas Astronautics Company facilities. These laboratories, designed and used for space vehicles, will require little or no modification for use in the Space Tug Program.

Vehicle PTV tests will be conducted in test cell J4 of the AEDC facility at Tullahoma. Test cell J4 provides an altitude simulation capability lacking in the test facilities at Huntsville. Thermal tests of the vehicle will be accomplished in the NASA High Vacuum facility utilizing an existing scaled

SPACE TUG STUDY

ADDITIONAL MANUFACTURING FACILITIES

DESCRIPTION	LEAD TIME	ROM COST OPTION 1 & 3	ROM COST OPTION 2
1. AGING OVEN 20 FT X 20 FT x 8 FT (325°F)	6 MONTHS	30,000	
2. AUTOCLAVE 16 FT DIA X 12 FT LONG (600°F)	10 MONTHS	130,000	
3. CHEM-MILL FACILITY 2 TANKS 20 FT X 20 FT X 12 FT	10 MONTHS	200,000	
4. ANODIZE FACILITY 20 FT X 20 FT X 10 FT TANKS	4 MONTHS	200,000	
5. CLEAN ROOM/10 TON BRIDGE CRANE 5000 SQ FT (100,000 CLASS)	8 MONTHS	250,000	
6. ACOUSTIC EMISSION TEST EQUIPMENT (PATE)		150,000	
7. ACOUSTIC EMISSION TEST EQUIPMENT (PATE)		75,000	
			1,035,000
8. CURING OVEN 16 FT X 16 FT X 8 FT (600°F)	6 MONTHS		[illegible]0,000
TOTAL		1,035,000	1,0[illegible]5,000

TEST FACILITIES

	NASA	DOD
1. MDAC HUNTINGTON BEACH LABS	-0-	-0-
2. NASA HUNTSVILLE HIGH VACUUM FACILITY	-0-	250,000
3. AEDC TULLAHOMA MARK 4 CHAMBER	1,250,000	-0-

TABLE 11.5-1

down and instrumented tank that will fit the 15 foot diameter chamber. These government facilities are available at no cost or at a nominal fee depending on the using agency (see Table 11.5-1).

11.5.2 Operations Facilities

The requirement for Tug launch facilities at ETR eill be satisfied with constuction of one new building 11.5.2-1, by modification and refurbishment of existing buildings and by use of Orbiter facilities that can be expanded or adapted to include Tug service (Figure 11.5.2-2)

At WTR, construction of a new Payload Processing facility (Figure 11.5.2-3) together with use of programmed Shuttle facilities expanded to satisfy Tug needs will provide the support required.

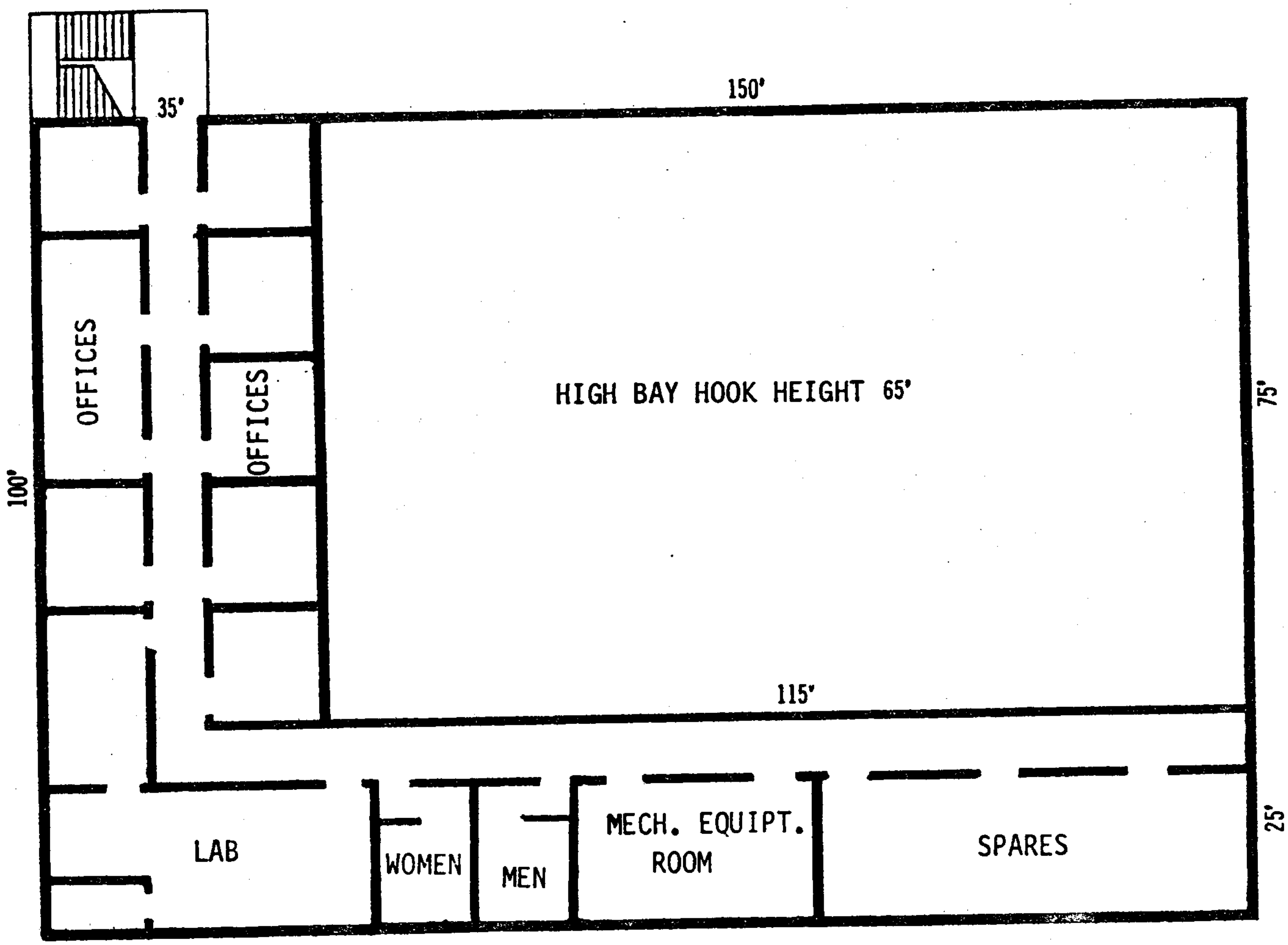
11.5.3 Facility Costs

A tabulation of these facilities' status and cost is presented in Table 11.5.3-1 and in Facility Description sheets.

Table 11.5-1

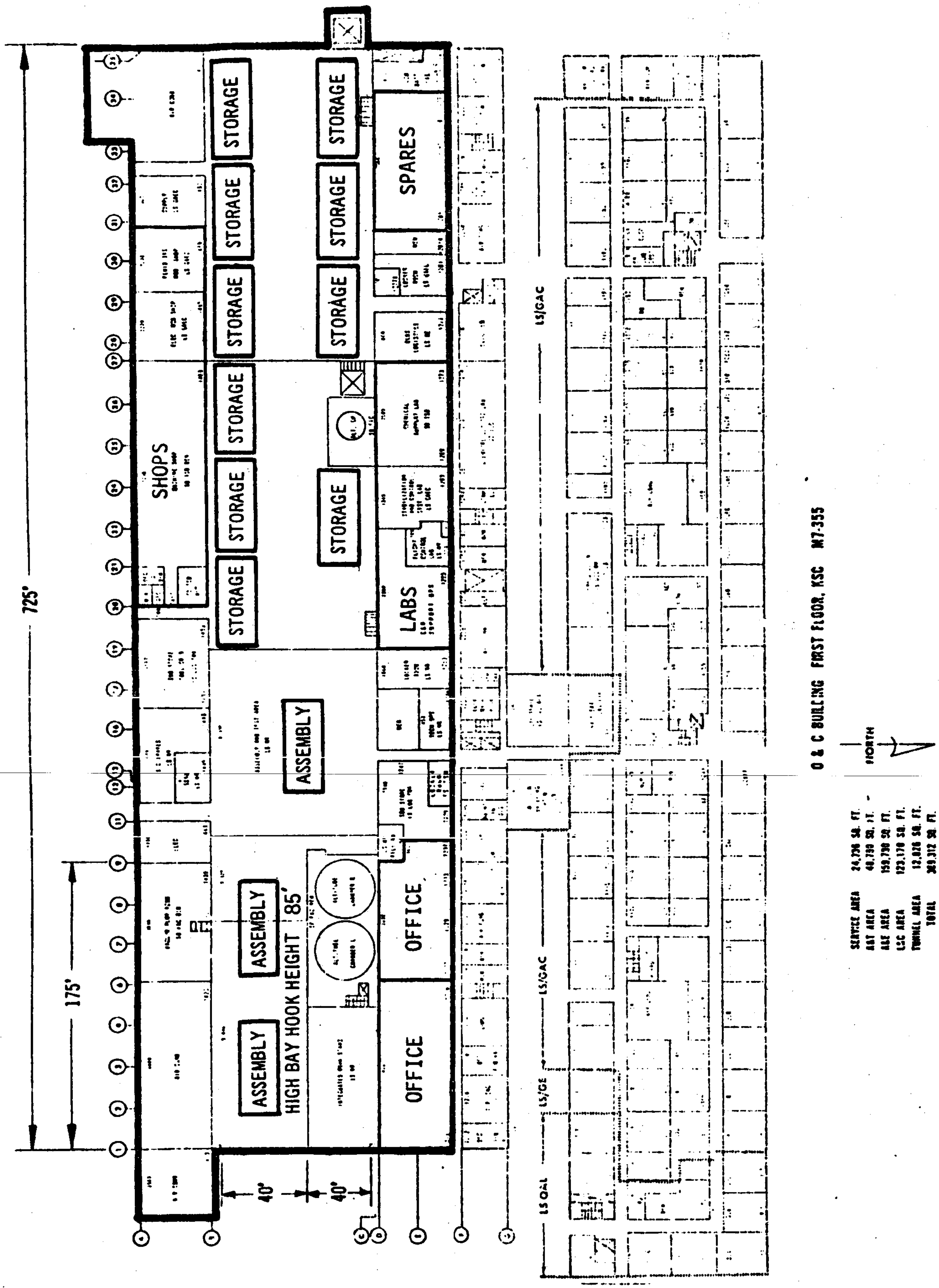
OPERATIONAL FACILITIES SUMMARY

FACILITY	ORIGIN	KSC	WTR
Tug Processing Facility	Modified KSC Bldg M7-355	500,000	
DOD Payload Processing Facility	New	500,000	
Payload Processing Facility	New		750,000
Maintenance and CO Facility	Modified Shuttle Facility	10,000	
Maintenance and CO Facility	Modified Shuttle Facility		10,000
Launch Service Structure	Modified Shuttle Facility	350,000	
Launch Service Structure	Modified Shuttle Facility		350,000
Launch Control Center	Modified Shuttle Facility	10,000	
Launch Control Center	Modified Shuttle Facility		-0-
Safing Facility	Modified Shuttle Facility	-0-	
Safing Facility	Modified Shuttle Facility		-0-
Storable Propellant Facility	Modified Shuttle Facility	-0-	
Storable Propellant Facility	Modified Shuttle Facility		-0-
Vertical Assembly Building	Modified Shuttle Facility	10,000	
Vertical Assembly Building	Modified Shuttle Facility		10,000
		1,380,000	1,120,000



PAYLOAD PROCESSING FACILITY KSC

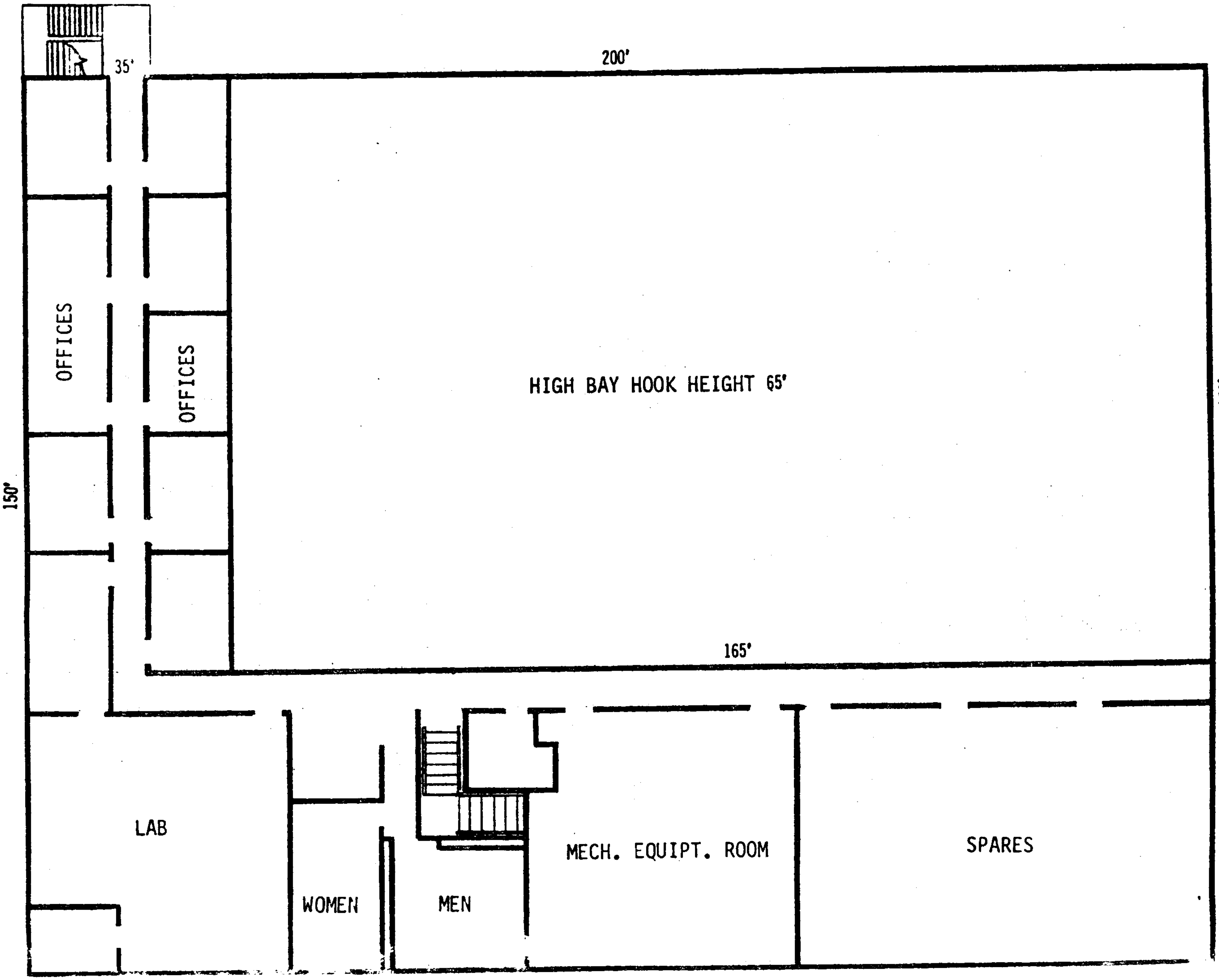
FIG 11.5.2-1



O & C BUILDING FIRST FLOOR, KSC M7-355

SERVICE AREA	24,776 SQ. FT.
A&T AREA	48,739 SQ. FT.
A&E AREA	159,790 SQ. FT.
LSC AREA	123,170 SQ. FT.
TUNNEL AREA	12,826 SQ. FT.
TOTAL	369,312 SQ. FT.

FIG. 11.5.2-2



AYL AD PROCESSING F LITY WTR

FIG 11.5.2-3

.6 Ground Support Equipment (GSE)

The results of the GSE task include the detailed definition of the GSE, quantities, price, development schedule, and GSE at each location for factory, Eastern Test Range (KSC) and Western Test Range (VAFB) which are required to support both NASA and DOD Tug missions. It also includes a definition of equipment that is Government Furnished Equipment (GFE) which is available from the Saturn and Delta program that is usable for Tug.

Overall Study/Program Objectives

The overall study/program objectives which relate to the GSE and software tasks are to:

(1) Low design, development, test and evaluation (DDT&E) for GSE and software for Space Tug capability.

(2) Reasonable turnaround and checkout philosphy.

(3) Flexible GSE to checkout many configurations of Tug/spacecraft.

(4) Utilize GFE as much as possible to reduce overall cost and not degrade checkout.

Methodology for Development of GSE and Software

The methodology for defining the GSE and software required for each option was defined as follows:

(1) Utilize the functional flows to establish equipment locations where hardware is required.

(2) Utilize vehicle hardware description to establish type of GSE required to checkout vehicle.

(3) Utilize vehicle function list, schematic, and instrumentation list has established number of functions across vehicle/GSE interface and number of functions to be monitored.

(4) Sized the GSE to percentage of existing GSE from similar programs - Saturn, Delta, and Skylab programs, Developed GSE hardware descriptions. The costing personnel then took actual cost for GSE hardware descriptions.

(5) Established a checkout philosophy similar to the Airline method of checkout using trend data from previous missions.

(6) Defined all interfaces and equipment required to checkout their interfaces and developed hardware description for the GSE.

(7) Developed factory, Tug Processing Facility, Payload Processing Facility, Orbiter Maintenance and Checkout, and launch pad checkout and GSE block diagrams. Developed AEDC and Integrated Avionics Test flows and block diagrams.

(8) Developed schedules for development of GSE and software.

(9) Developed software development and operation task flows.

(10) Define all software programs required for checkout, maintenance, and support programs.

(11) Software personnel sized each program defining number of words of memory required for each program. Multiply the memory words times a certain dollar rate establish the cost for development of that program. These programs were then compared to similar programs on the Delta program to establish confidence in our software numbers developed for this program. Sustaining was established by sizing the number of memory words that would change as the vehicle configuration changes. The same iterative process was utilized. In some cases a percentage was utilized by our software personnel best judgement and experience from developing software on similar programs under contract to MDAC.

(12) We review the GFE from other programs and establish quantities, and type available for use on the Tug program.

Tug Checkout Philosophy

A. Factory Checkout (post-manufacturing)

1. Tug/GSE Interface Test and Continuity Test - The electrical interfaces between the Tug and GSE will be tested to verify that the proper impedance exists looking into the Tug. (The GSE will be checked for proper operation by appropraite self-test procedures.) The Tug's wire-harnesses will also be continuity tested to prove correct wiring and electrical conduction. These tests will be completed before power is first applied. Purpose of these tests is to minimize

the possibility of vehicle damage due to wiring anomalies during the ensuing power-on testing.

2. Subsystem Testing - This phase of the testing involves any calibration of components on the Tug that must be accomplished before power is turned on. Power is then applied to vehicle buses and independent subsystems sequentially energized and verified for proper power consumption. Additional calibration of certain Tug components may take place at this time.

   Independent testing of each subsystem follows with tests designed to detect failures of out-of-tolerance conditions down to the Line Replaceable Unit (LRU) level. Individual measurements will use the smallest tolerances which can be reliably measured which indicate the proper function of any component. These tolerances generally correspond to the tolerances stated in the component specifications plus any measuring system uncertainty figure.

   In some cases, complete subsystem checkout cannot be accomplished during post-manufacturing testing because of the need for extraordinary conditions involving cryogenic temperatures, propellant flow, engine ignition, hypergolic fuels, etc. In such circumstances, testing will be accomplished to the greatest extent possible using simulators and/or software simulation techniques. It is possible that pre-assembly testing of these components under proper conditions must suffice until prelaunch conditions provide the necessary environment for final component validation.

3. System Testing - Once all calibration and subsystem testing are complete, a system test in which all subsystems are turned on and operated together will be performed. Special real-time and off-line data analyses will verify that no incompatibility or interference situation exists. A generalized flight sequence will be followed during this test.

Additionally, this test will provide a time for preliminary flight software to be loaded and partially validated.

For a selected number of early Tugs, an EMC test will be run in conjunction with the system test in order to obtain sufficient data to determine effect of electromagnetic radiation.

Measurement tolerances for system testing will not be as severe as those used for subsystem testing. The intent in this case is to use the measurements to indicate proper operation of total subsystems rather than individual components or LRUs. Fault isolation during system testing may use tighter tolerances, however.

B. Launch Site Testing

The testing which a Tug receives at the launch area is essentially of two classifications. The first class is the normal scheduled maintenance and checkout which each Tug receives after each mission. The other class is maintenance and checkout which was not scheduled and is done because of data received from the Tug during flight. This data may indicate hard failures or may provide additional data points from which trend analysis can show imminent failures. (Similar to Airline checkout philosophy).

1. Testing on Tugs which have just returned from a mission - These tests are performed in the Safing area and consit mainly of a test of the fuel cells (program Option 2 and 3F only) before they are deactivated. The Tug goes next to the Tug Processing Facility where scheduled and unscheduled maintenance is performed, re-validation checks are made, calibration and testing of the scheduled calibration items is done, and an "all systems test" is run. Measurement tolerances for these tests are similar to those of the corresponding tests done during post-manufacturing checkout, taking into account any differences in measuring systems.

When this testing is complete, the Tug may go into a storage area for an indefinite length of time or it may continue processing for immediate launch.

For those Tugs continuing processing, the next test area will generally be the Spacecraft Mating Facility where the Tug payload is installed. Checkout here will involve testing of the Tug hardware and the interface which supports the payload.

The next test area is the Tug-Orbiter Mating Facility where the Tug is placed in the Orbiter cargo bay and electrically mated. It is recognized that some launch situations will require Tug-Orbiter mating on the launch pad. The checkout performed in either situation is identical. The flight software for both the Tug and Orbiter-Tug checkout computer will be loaded and validated after mating. The Orbiter-Tug interface will also be functionally validated.

Final Tug hardware and software validation will occur on the pad with a Simulated Flight Test in which the flight software and an integrated vehicle can together be used in a simulated flight situation. Checkout tolerances will be those used in flight except in certain cases where the ground computer intervenes with special checkout or fault isolation routines. This flight test is followed by propellant loading and the final countdown. These procedures involve a certain amount of testing to insure proper loading, flight readiness, etc., however, the testing is minimal and uses measurement tolerances which indicate go-no go situations rather than detailed component calibration information. This status monitoring is done through umbilical wiring, downlink readouts, and possibly a direct computer memory access capability.

2. Testing Tugs after storage - Tugs entering storage were essentially ready for payload mating, but because of the calibration drift which occurs with time, a full calibration and

verification cycle, including individual subsystem tests and the final all systems test, must be accomplished in the Tug Processing Facility before payload mating. The subsystem tests are necessary because subsystem data from the last flight may no longer reflect the true Tug condition. These subsystem tests will generally be identical to those used in post-manufacturing chec,out except for differences made necessary by the checkout equipment and facilities.

3. Testing on New Tugs - These Tugs enter the Tug Processing Facility and receive calibration of those devices which require it prior to each launch. An all systems test is then performed and the Tug continues the launch preparation process.

It is assumed that new Tugs have just completed post-manufacturing checkout and therefore do not need full calibration and subsystem testing. If there is any delay which exceeds calibration time limits, a new Tug must be treated as if it had been in storage and undergo full calibration and subsystem checkout.

GSE - Option Summary

Option 1 Features:

(a) GSE is sized for fleet size of 13 vehicles for cradles, covers and transporters.

(b) Guidance and Navigation checkout equipment GFE from Delta program.

(c) Battery checkout GFE from Saturn program.

(d) Factory GSE is shipped to VAFB to become launch checkout equipment for one pad. Feasible since schedule delivery of 13 vehicles allows enough time to accomplish this.

(e) Provide only one pad of GSE at VAFB since launch rates are low from WTR and one set of hardware can support program launch rate from WTR.

(f) Utilizes maximum GFE from Saturn program where possible to support KSC.

Option 2 Features:

(a) GSE is sized for fleet size of 13 vehicles for cradles, covers, and transporters.

(b) New Guidance and Navigation checkout equipment is required.

(c) New fuel cell checkout equipment is required.

(d) New laser radar checkout equipment is required.

(e) Factory GSE is shipped to VAFB to become launch checkout equipment for one pad. Feasible since schedule delivery of 13 vehicles allows enough time to accomplish this.

(f) Provide only one pad of GSE at VAFB since launch rates are low from WTR and one set of hardware can support launch rate from WTR.

(g) Utilizes maximum GFE from Saturn program where feasible to support KSC.

Option 3 Initial Features:

(a) GSE is sized for fleet sizes of five vehicles for cradles, covers, and transporters.

(b) All other features are the same as option 1.

Option 3 final features:

(a) GSE is sized for a fleet size of nine vehicles for cradles, covers and transporters.

(b) Features are the same as option 2 except two pads of GSE and provided at WTR and factory set is available for depot maintenance or future production. In options 1, 2 and 3 initial the factory set of hardware has been deployed to VAFB as the launch checkout equipment. In option 3 you attain low DDT&E during the initial phase and still have GSE developed during the final configuration to support any configuration checkout and testing turnaround rate. The factory set can be utilized for modification and development of future changes or be moved to the launch site to enable faster turnaround at either KSC or WTR as the situation warrants the higher launch rates.

11.6.2 GSE Description Sheets

All GSE Description Sheets can be found in Appendix E, Section 11.10.

11.6.3 Alternate Site GSE

Alternate Sites were eliminated by groundule and thus this section is not applicable.

11.7 Maintenance/Refurbishment/Checkout

Refurbishment/Reuse Philosophy

The refurbishment/reuse analysis is an essential part of the development of a reusable space tug - one which is capable of performing the required type and number of missions with the minimum DDT&E, Production and Operations costs. The cost of reuse primarily depends on the magnitude and frequency of refurbishment requirements and the fleet size to which they are applied. Therefore, a basic objective of this analysis is to determine means of minimizing the refurbishment requirements over the program life. Reusability is expressed as the number of reuses a Tug can achieve before reaching a point at which the original reliability level cannot be restored on the basis of technical or economic feasibility.

The MDAC refurbishment/reuse philosophy considers the Tug vehicle and its subsystems capable of operating throughout the program life with refurbishment/ replacement of subsystem life-limited components as required. This philosophy is based on the premise that the structures subsystem is the primary consideration in determining an optimum number of reuses. Structures analyses reveal no life limitation for this subsystem and include an evaluation of flight and ground stress loads, fracture mechanics and structures materials. The other subsystems-Thermal Control, Avionics, Propulsion and Orbiter Interface are not life limited at the subsystem level; however all subsystems will experience scheduled and unscheduled maintenance ($\overline{M}$) and refurbishment ($\overline{R}$) at the assembly, component or lower levels of detail during the the life of the Tug program. Table 11.7-1 summarizes the Tug subsystem life limitations.

Each subsystem of all program options was examined to identify its maintenance/ refurbishment characteristics requirements and associated costs per refurbishment and over a spectrum of 20, 50 and 100 reuses. These data are shown in Tables 11.7-2 through 11.7-21. The maintenance/refurbishment cycle functional flows are shown in Section 11.3.3, the time lines are contained in Section 11.3.6 and the task descriptions together with the GSE and manpower requirements are documented in Section 11.3.7.

The number of reuses for subsystem components was derived from:

- Analysis of Tug subsystems and components
- Component manufacturer's recommendations regarding service life and refurbishment criteria in terms of operating hours and cycles.
- Reliability predictions
- Engineering judgement based on experience with similar equipment designs.

Increasing the number of missions before refurbishment (reducing refurbishment frequency) impacts the DDT&E investment by establishing a requirement to;

- Develop/test long life components
- Develop/test high reliability components

In summary, no life limitations are evident at the Tug vehicle and subsystem level; however, there are components with limited life at WBS level 6 and below. These life limitations together with the associated refurbishment criteria, frequency and cost are shown in Tables 11.7-1 through 11.7-21.

Tug Checkout Philosophy

A. FACTORY Checkout (post-manufacturing)

1. Tug/GSE Interface Test and Continuity Test - The electrical interfaces between the Tug and GSE will be tested to verify that the proper impedance exists looking into the Tug. (The GSE will be checked for proper operation by appropriate self-test procedures). The Tug's wire-harnesses will also be continuity tested to prove correct wiring and electrical conduction. These tests will be completed before power is first applied. Purpose of these tests is to minimize the possibility of vehicle damage due to wiring anomalies during the ensuing power-on testing.
2. Subsystem Testing - This phase of the testing involves any calibration of components on the Tug that must be accomplished before power is turned on. Power is then applied to vehicle buses and independent subsystems sequentially energized and verified for proper power consumption. Additional calibration of certain Tug components may take place at this time.

Measurement tolerances for system testing will not be as severe as those used for subsystem testing. The intent in this case is to use the measurements to indicate proper operation of total subsystems rather than individual components or LRUs. Fault isolation during system testing may use tighter tolerances, however.

B. Launch Site Testing

The testing which a Tug receives at the launch area is essentially of two classifications. The first class is the normal scheduled maintenance and checkout which each Tug receives after each mission. The other class is maintenance and checkout which was not scheduled and is done because of data received from the Tug during flight. This data may indicate hard failures or may provide additional data points from which trend analysis can show imminent failures.

1. Testing on Tugs which have just returned from a mission - These tests are performed in the Safing area and consist mainly of a test of the fuel cells (program Option 2 and 3F only) before they are deactivated. The Tug goes next to the Tug Processing Facility where scheduled and unscheduled maintenance is performed, re-validation checks are made, calibration and testing of the scheduled calibration items is done, and an "all systems test" is run. Measurement tolerances for these tests are similar to those of the corresponding tests done during post-manufacturing checkout, taking into account any differences in measuring systems.

   When this testing is complete, the Tug may go into a storage area for an indefinite length of time or it may continue processing for immediate launch.

   For those Tugs continuing processing, the next test area will generally be the Spacecraft Mating Facility where the Tug payload is installed. Checkout here will involve testing of the Tug hardware and the interface which supports the payload.

Independent testing of each subsystem follows with tests designed to detect failures or out-of-tolerance conditions down to the Line Replaceable Unit (LRU) level. Individual measurements will use the smallest tolerances which can be reliably measured which indicate the proper function of any component. These tolerances generally correspond to the tolerances stated in the component specifications plus any measuring system uncertainty figure.

In some cases, complete subsystem checkout cannot be accomplished during post-manufacturing testing because of the need for extraordinary conditions involving cryogenic temperatures, propellant flow, engine ignition, hypergolic fuels, etc. In such circumstances, testing will be accomplished to the greatest extent possible using simulators and/or software simulation techniques. It is possible that pre-assembly testing of these components under proper conditions must suffice until prelaunch conditions provide the necessary environment for final component validation.

3. System Testing - Once all calibration and subsystem testing are complete, a system test in which all subsystems are turned on and operated together will be performed. Special real-time and off-line data analyses will verify that no incompatibility or interference situation exists. A generalized flight sequence will be followed during this test.

   Additionally, this test will provide a time for preliminary flight software to be loaded and partially validated.

   For a selected number of early Tugs, an EMC test will be run in conjunction with the system test in order to obtain sufficient data to determine effect of electromagnetic radiation.

The next test area is the Tug-Orbiter Mating Facility where the Tug is placed in the Orbiter cargo bay and electrically mated. It is recognized that some launch situations will require Tug-Orbiter mating on the launch pad. The checkout performed in either situation is identical. The flight software for both the Tug and Orbiter-Tug checkout computer will be loaded and validated after mating. The Orbiter-Tug interface will also be functionally validated.

Final Tug hardware and software validation will occur on the pad with a Simulated Flight Test in which the flight software and an integrated vehicle can together be used in a simulated flight situation. Checkout tolerances will be those used in flight except in certain cases where the ground computer intervenes with special checkout or fault isolation routines. This flight test is followed by propellant loading and the final countdown. These procedures involve a certain amount of testing to insure proper loading, flight readiness, etc., however, the testing is minimal and uses measurement tolerances which indicate go-no go situations rather than detailed component calibration information. This status monitoring is done through umbilical wiring, downlink readouts, and possibly a direct computer memory access capability.

2. Testing Tugs after storage - Tugs entering storage were essentially ready for payload mating, but because of the calibration drift which occurs with time, a full calibration and verification cycle, including individual subsystem tests and the final all systems test, must be accomplished in the Tug Processing Facility before payload mating. The subsystem tests are necessary because subsystem data from the last flight may no longer reflect the true Tug condition. These subsystem tests will generally be identical to those used in post-manufacturing checkout except for differences made necessary by the checkout equipment and facilities.

3. Testing on new Tugs - These Tugs enter the Tug Processing Facility and receive calibration of those devices which require it prior to each launch. An all systems test is then performed and the Tug continues the launch preparation process.

It is assumed that new Tugs have just completed post-manufacturing checkout and therefore do not need full calibration and subsystem testing. If there is any delay which exceeds calibration time limits, a new Tug must be treated as if it had been in storage and undergo full calibration and subsystem checkout.

Table 11.7-1 (Sheet 1 of 2)

TUG SUBSYSTEM LIFE LIMITATIONS

Subsystems/Components	Life Limiting Factors
<u>Structures</u>	None Evident
• Fuel Tank and Support	
• Oxidizer Tank and Support	
• Body Structure	
• Thrust Structure	
• Meteoroid Shield	
• Payload Interface	
<u>Thermal Control</u>	None Evident
• Fuel Tank Insulation	
• Oxidizer Tank Insulation	
• Insulation Purge	
<u>Avionics</u>	None Evident
• Data Management System	None Evident
• Guidance, Navigation and Control	IMU requires refurbishment after 2,000 hours
• Communications	Tape recorders require refurbishment after 1,000 hours
• Instrumentation	None Evident
• Electrical Power	Primary Power and TVC Batteries are expendable — Replaced after each flight. Fuel cells require replacement after 5,000 hours.
• Power Distribution and Control	None Evident
<u>Propulsion</u>	
• Main Engine	Category I and IIA RL-10 Engines require refurbishment after 5 hours and/or 190 starts
• Main Engine Support	None Evident
• ACPS Engines	Mono-propellant thrusters require catalyst bed replacement after 4,000 seconds burn time
• ACPS Engine Support	None Evident

Table 11.7-1 (Sheet 2 of 2)

TUG SUBSYSTEM LIFE LIMITATIONS

Subsystems/Components	Life Limiting Factors
Orbiter Interface • Structures • Interface Panels • Abort Provisions	None Evident ↓

Table : 11.7-2

IMU REFURBISHMENT CHARACTERISTICS

GN&C-Inertial Measurement Units (IMU)	Qty per Tug	Operating Time (Hours)			Refurbishment Criteria-Operating Time (Hours)	Missions Before Scheduled Refurbishment	Scheduled Refurbishments per No. of Reuses		
		Flight	Ground	Total			20	50	100
Program Option 1	2	36	54	90	2K	22	-	2	4
Program Option 2	2	144	54	198	2K	10	2	5	10
Program Option 3I	2	36	54	90	2K	22	-	2	4
Program Option 3F	2	144	54	198	2K	10	2	5	10

Note:

1. Gyros are the principal refurbishment requirement
2. IMU refurbishment estimated at 30% of new IMU cost

Table : 11.7-3

TAPE RECORDER REFURBISHMENT CHARACTERISTICS

Communications Tape Recorders	Qty per Tug	Operating Time (Hours)			Refurbishment Criteria-Operating Time (Hours)	Missions Before Scheduled Refurbishment	Scheduled Refurbishments per No. of Reuses		
		Flight	Ground	Total			20	50	100
Program Option 1	2	13	13	26	1K	38	-	1	2
Program Option 2	2	52	52	104	1K	10	2	5	10
Program Option 3I	2	13	13	26	1K	38	-	1	2
Program Option 3F	2	52	52	104	1K	10	2	5	10

Note:

1. After each flight

- Change Tape Cassettes
- Clean Tape Heads
- Clean inside of recorder

2. Tape transport mechanism, bearings, etc., are principal refurbishment reqmt.

3. Recorder refurbishment estimated at 25% of new recorder cost.

Table 11.7-4

PROGRAM OPTION BATTERY REQUIREMENTS

Expendable Battery Replacement Costs	Total Program Quantity *	Battery Quantity Per Tug		Estimated Cost per Replacement	Estimated Cost for Program Option Flight Schedule	Estimated Replacement Costs per No. of Reuses per Tug - $K		
		Primary Power	TVC			20	50	100
Program Option 1	225	2	1	$37.3K	$8,392.5K	746	1,865	3,730
Program Option 2	220	-	1	$ 2.3K	$ 506K	46	115	230
Program Option 3I	150	2	1	$37.3K	$5,595K	746	1,865	3,730
Program Option 3F	222	-	1	$ 2.3K	$ 510.6K	46	115	230

Note:

*Total Program Quantity = Total Number of Program Scheduled Flights less the Ship Set delivered with each new tug plus 5 percent spares to compensate for ground operations contingencies.

Table 11.7-5

FUEL CELL REUSE CHARACTERISTICS

Fuel Cells	Maximum Flights Per TUG	Operating Time (Hours)			Replacement Criteria- Operating Time (Hours)	Missions Before Scheduled Replacement	Scheduled Replacements per TUG Per No. of Reuses		
		Flight	Ground	Total			20	50	100
Program Option 2	25	144	6	150	5,000	33	-	1	3
Program Option 3F	37	144	6	150	5,000	33	-	1	3

Table - 11.7-6

FUEL CELL REPLACEMENT

Fuel Cell Replacement Requirement Program Option 3F	83			84			85			86			87			88			89			90			Total	
Flight Requirement	0			27			28			28			29			33			33			40			218	
Expendable Flights																										
Reflight/Loss							1									1						1			3 221	
TUG ID	Y	C	R	Y	C	R	Y	C	R	Y	C	R	Y	C	R	Y	C	R	Y	C	R	Y	C	R	C	R
5				10	10	0	10	20	0	6	26	0	4	30	0	5	35	1	2	37	0				37	1
6				10	10	0	10	20	0	2	22	0	4	26	0	6	32	0	4	36	1	1	37	0	37	1
7				7	7	0	8	15	0	2	17	0	3	20	0	3	23	0	5	28	0	9	37	1	37	1
8										9	9	0	6	15	0	6	21	0	6	27	0	10	37	1	37	1
9										9	9	0	6	15	0	4	19	0	8	27	0	10	37	1	37	1
10													6	6	0	9	15	0	8	23	0	10	33	1	33	1
Total Replacements	0			0			0			0			0			1			1			4			6	

NOTE: 1. Y = Yearly, C = Cum., and R = Replacement

2. Two fuel cells/replacement

Table 11.7-7

MAIN ENGINE REFURBISHMENT CHARACTERISTICS

Main Engines	Service Life		Refurbishment Criteria		Usage per Mission		Missions before Scheduled Refurbishment	Scheduled Refurbishments Per No. of Reuses		
	Cum. Hours	Cum. Cycles	Cum. Hours	Cum. Cycles	Cum. Hours	Cum. Cycles		20	50	100
Category I RL-10	Indef.	190	5	190	0.5	9	10	2	5	10
Category IIA RL-10	Indef.	190	5	190	0.5	9	10	2	5	10
Category IV RL-10	Indef.	300	10	300	0.5	9	20	1	2	5
Aerospike	50	1500	10	300	0.5	9	20	1	2	5
Advanced Space Engine	40	1200	10	300	0.5	9	20	1	2	5

Table 11.7-8

MAIN ENGINE REFURBISHMENT COSTS

Main Engines	Average Production Unit Cost - $K	Refurbishment as a % of New Engine Cost	Cost per Refurbishment $K	Missions before Scheduled Refurbishment	Scheduled Refurbishment Costs - $K Per No. of Reuses		
					20	50	100
Category I RL-10	488	30	146	10	292	730	1,460
Category IIA RL-10	558	30	167	10	334	835	1,670
Category IV RL-10	628	30	188	20	188	376	940
Aerospike	767	33	253	20	253	506	1,265
Advanced Space Engine	837	33	276	20	276	552	1,380

Table 11.7-9

MAIN ENGINE REFURBISHMENT CHARACTERISTICS COMPARISON BY PROGRAM OPTION

Main Engines	Service Life		Refurbishment Criteria		Usage per Mission		Missions before Scheduled Refurbishment	Scheduled Refurbishments per Program Option			
	Cum. Hours	Cum. Cycles	Cum. Hours	Cum. Cycles	Cum. Hours	Cum. Cycles		1	2	3I	3F
Category I RL-10	Indef.	190	5	190	0.5	9	10	18	18	12	18
Category IIA RL-10	Indef.	190	5	190	0.5	9	10	18	18	12	18
Category IV RL-10	Indef.	300	10	300	0.5	9	20	8	9	4	6
Aerospike	50	1500	10	300	0.5	9	20	8	9	4	6
Advanced Space Engine	40	1200	10	300	0.5	9	20	8	9	4	6

Table 11.7-10

MAIN ENGINE REFURBISHMENT COST COMPARISON BY PROGRAM OPTION

Main Engines	Average Production Unit Cost - $K	Refurbishment as a % of New Engine Cost	Cost per Refurbishment $K	Missions before Scheduled Refurbishment	Scheduled Refurbishment Costs - $K per Program Option			
					1	2	3I	3F
Category I RL-10	488	30	146	10	2,628	2,628	1,752	2,628
Category IIA RL-10	558	30	167	10	3,006	3,006	2,004	3,006
Category IV RL-10	628	30	188	20	1,504	1,692	752	1,128
Aerospike	767	33	253	20	2,024	2,277	1,012	1,518
Advanced Space Engine	837	33	276	20	2,208	2,484	1,104	1,656

Table 11.7-11

Category I RL-10 Main Engine Change Requirement Program Option 1	80	81	82	83	84	85	86	87	88	89	90	Total
Flight Reqmt	3	14	16	28	27	21	20	27	20	27	20	223
Expndbl. Flights					2		1	1		3	1	(8)
Reflight/Loss				1			1			1		3
												226

Tug ID	Y = Yearly, C = Cum. EC = Engine Change	80			81			82			83			84			85		
		Y	C	EC	Y	C	EC	Y	C	EC	Y	C	EC	Y	C	EC	Y	C	EC
1		2	2	0	4	6	0	2	8	0	3	11	1	3	14	0			
2		1	1	0	6	7	0	2	9	0	5	14	1	6	20	0			
3					4	4	0	4	8	0	6	14	1	6	20	1	2	22	0
4								4	4	0	6	10	1	4	14	0	3	17	0
5								2	2	0	4	6	0	4	10	1	4	14	0
6								2	2	0	4	6	0	4	10	1	4	14	0
7																	8	8	0
8																			
9																			
10																			
Total Engine Changes		0			0			0			4			3			0		

Tug ID	86			87			88			89			90			Total
	Y	C	EC	Y	C	EC	Y	C	EC	Y	C	EC	Y	C	EC	C/EC
1																14/1
2																20/1
3	2	24	0													24/2
4	3	20	1	2	22	0										22/2
5	4	18	0	2	20	1	2	22	0	2	24	0				24/2
6	4	18	0	2	20	1	2	22	0	2	24	0				24/2
7	7	15	1	4	19	0	3	22	1	2	24	0				24/2
8				10	10	1	10	20	1	2	22	0	2	24	0	24/2
9				7	7	0	3	10	1	8	18	0	6	24	1	24/2
10										11	11	1	12	23	1	23/2
Total Engine Changes	2			3			3			1			2			18

Table 11.7-12

Category IIA RL-10 Main Engine Change Requirement Program Option 2	80	81	82	83	84			85			86			87			88			89			90			Total
Flight Reqmt					20			32			35			37			30			33			33			220
Expndbl. Flights											1			1						3			1			(6)
Reflight/Loss											1						1						1			3
																										223
Tug ID — Y = Yearly, C = Cum. EC = Engine Change					Y	C	EC	Y	C	EC	Y	C	EC	Y	C	EC	Y	C	EC	Y	C	EC	Y	C	EC	C/EC
1					8	8	0	11	19	1	5	24	1													24/ 2
2					7	7	0	11	18	1	4	22	1	2	24	0										24/ 2
3					5	5	0	4	9	0	4	13	1	7	20	1	2	22	0	2	24	0				24/ 2
4								6	6	0	7	13	1	7	20	1	2	22	0	2	24	0				24/ 2
5											10	10	1	8	18	0	3	21	1	4	25	0				25/ 2
6											5	5	0	7	12	1	4	16	0	4	20	1	5	25	0	25/ 2
7														3	3	0	4	7	0	7	14	1	11	25	1	25/ 2
8														3	3	0	7	10	1	6	16	0	9	25	1	25/ 2
9																	8	8	0	8	16	1	8	24	1	25/ 2
Total Engine Changes					0			2			5			3			2			3			3			18

Table 11.7-13

Category I RL-10 Main Engine Change Requirement Program Option 3I	80			81			82			83			84			85			86			87			88			89			90	Total
Flight Reqmt	3			21			22			36			17			13			13			11			4			8				148
Expndbl. Flight																			1			1						2			1	(4)
Reflight/Loss							1																									1
																																149
Tug ID / Y = Yearly, C = Cum. EC = Engine Change	Y	C	EC	Y	C	EC	Y	C	EC	Y	C	EC	Y	C	EC	Y	C	EC	Y	C	EC	Y	C	EC	Y	C	EC	Y	C	EC		C/EC
1	2	2	0	9	11	1	6	17	0	9	26	1	5	31	1	5	36	0	1	37	0											37/3
2	1	1	0	8	9	0	4	13	1	9	22	1	5	27	0	3	30	1	5	35	0	2	37	0								37/3
3				4	4	0	2	6	0	10	16	1	2	18	0	0	18	0	6	24	1	6	30	1	3	33	0	4	37	0		37/3
4							10	10	1	8	18	0	5	23	1	5	28	0	1	29	0	3	32	1	1	33	0	4	37	0		37/3
Total Engine Change	0			1			2			3			2			1			1			2			0			0				12

Table 11.7-14

Category I RL-10 Main Engine Change Requirement Program Option 3F	80	81	82	83	84	85	86	87	88	89	90	Total
Flight Reqmt					27	28	28	29	33	33	40	218
Expndbl. Flight												
Reflight/Loss						1			1		1	3
												221

Tug ID	Y = Yearly, C = Cum. EC = Engine Change	80	81	82	83	84 Y	84 C	84 EC	85 Y	85 C	85 EC	86 Y	86 C	86 EC	87 Y	87 C	87 EC	88 Y	88 C	88 EC	89 Y	89 C	89 EC	90 Y	90 C	90 EC	C/EC
5						10	10	1	10	20	1	6	26	0	4	30	1	5	35	0	2	37	0				37/3
6						10	10	1	10	20	1	2	22	0	4	26	0	6	32	1	4	36	0	1	37	0	37/3
7						7	7	0	8	15	1	2	17	0	3	20	1	3	23	0	5	28	0	9	37	1	37/3
8												9	9	0	6	15	1	6	21	1	6	27	0	10	37	1	37/3
9												9	9	0	6	15	1	4	19	0	8	27	1	10	37	1	37/3
10															6	6	0	9	15	1	8	23	1	10	33	1	33/3
Total Engine Changes						2			3			0			4			3			2			4			18

Table 11.7-15

ACPS REFURBISHMENT CHARACTERISTICS

Mono Propellant ACPS	Thruster Burn Time Data			Valve Cycle Data			Scheduled Refurbishments per No. of Reuses		
	Catalyst Life in Seconds	Burn Time per Mission	Missions Before Refurb.	Valve Cycle Life	Duty Cycles per Mission	Missions Before Refurb.	20	50	100
36 Hour Mission									
• 25 Lb. Thruster (Forward Firing Axial & All Tangential)	4,000	40	100	200K	647	309	-	-	-
• 25 Lb. Thruster (Aft Firing Axial)	4,000	340	12	200K	520	384	1	4	8

Note:

1. Mission impulse = 16,291 lb sec with equal distribution of burn time.
2. Aft firng axial thrusters burn an additional 300 seconds/thruster for main propulsion propellant settling.

Table 11.7-16

ACPS REFURBISHMENT COSTS

ACPS Thrusters - Mono-Propallant	Average Production Unit Cost $K	Quantity per Tug	Missions Before Scheduled Refurbishment	Cost per Refurbishment $K per Tug	Scheduled Refurbishment Costs - $K - per No. of Reuses 20	50	100
36 Hour Mission							
• 25 Lb Thruster (Aft Firing Axial)	5,98 (1)	4	12	9.6 (2)	9.6	38.4	76.8

Note:

(1) Per Thruster

(2) Refurbishment Cost estimated at 40% of New Thruster Cost.

Table: 11.7-17

ACPS (Mono-Propellant) Thruster Change Requirement Program Option No. 1	80			81			82			83			84			85			86			87			88			89			90			Total
Flight Reqmt	3			14			16			28			27			21			20			27			20			27			20			223
Expndbl. Flights													2						1			1						3			1			(8)
Reflight/Loss										1									1									1						3
																																		226
Tug ID / Y = Yearly, C = Cum. TC = Thruster Change	Y	C	TC	Y	C	TC	Y	C	TC	Y	C	TC	Y	C	TC	Y	C	TC	Y	C	TC	Y	C	TC	Y	C	TC	Y	C	TC	Y	C	TC	C/TC
1	2	2	0	4	6	0	2	8	0	3	11	0	3	14	1																			14/1
2	1	1	0	6	7	0	2	9	0	5	14	1	6	20	0																			20/1
3				4	4	0	4	8	0	6	14	1	6	20	0	2	22	0	2	24	1													24/2
4							4	4	0	6	10	0	4	14	1	3	17	0	3	20	0	2	22	0										22/1
5							2	2	0	4	6	0	4	10	0	4	14	1	4	18	0	2	20	0	2	22	0	2	24	1				24/2
6							2	2	0	4	6	0	4	10	0	4	14	1	4	18	0	2	20	0	2	22	0	2	24	1				24/2
7																8	8	0	7	15	1	4	19	0	3	22	0	2	24	1				24/2
8																						10	10	0	10	20	1	2	22	0	2	24	1	24/2
9																						7	7	0	3	10	0	8	18	1	6	24	1	24/2
10																												11	11	0	12	23	1	23/1
Total Thruster Changes	0			0			0			2			2			2			2			0			1			4			3			16

Note: 4 Thrusters/Change

Table 11.7-18

ACPS (Mono-Propellant) Thruster Change Requirement Program Option No. 3I		80			81			82			83			84			85			86			87			88			89			90	Total
Flight Reqmt		3			21			22			36			17			13			13			11			4			8				148
Expndbl. Flights																				1			1						2				(4)
Reflight/Loss								1																									1
																																	149
Tug ID	Y = Yearly, C = Cum. TC = Thruster Change	Y	C	TC	Y	C	TC	Y	C	TC	Y	C	TC	Y	C	TC	Y	C	TC	Y	C	TC	Y	C	TC	Y	C	TC	Y	C	TC		C/TC
1		2	2	0	9	11	0	6	17	1	9	26	1	5	31	0	5	36	1	1	37	0											37/3
2		1	1	0	8	9	0	4	13	1	9	22	0	5	27	1	3	30	0	5	35	0	2	37	1								37/3
3					4	4	0	2	6	0	10	16	1	2	18	0	0	18	0	6	24	1	6	30	0	3	33	0	4	37	1		37/3
4								10	10	0	8	18	1	5	23	0	5	28	1	1	29	0	3	32	0	1	33	0	4	37	1		37/3
Total Thruster Changes		0			0			2			3			1			2			1			1			0			2				12
Note: 4 Thrusters/Change																																	

Table 11.7-19

ACPS REFURBISHMENT CHARACTERISTICS

Bi Propellant ACPS	Quantity Per Tug	Thruster Burn Time Data: Thruster Life in Seconds	Thruster Burn Time Data: Burn Time per Mission	Thruster Burn Time Data: Missions Before Refurb.	Valve Cycle Data: Valve Cycle Life	Valve Cycle Data: Duty Cycles per Mission	Valve Cycle Data: Missions Before Refurb.	Scheduled Refurbishments per No. of Reuses: 20	50	100
6 Day Mission										
ACPS Engines										
• 100 Lb Axial	8	180K	517	348	--	--	--	--	--	--
• 25 Lb Tangential	8	180K	837	215	--	--	--	--	--	--
ACPS Engine Support										
• Axial Thruster Valve Cycling	--	--	--	--	300K	2536	118	--	--	--
• Tangential Thruster Valve Cycling	--	--	--	--	300K	2734	109	--	--	--

Note:

1. Axial Thruster Impulse = 51,723 lb sec
2. Tangential Thruster Impulse = 20,937 lb sec

Table 11.7-20

ACPS REFURBISHMENT CHARACTERISTICS – STORABLE VS CRYOGENIC

ACPS Candidates	Service Life	Operating Time per Mission	Refurbishment Criteria	Missions before Scheduled Refurbishment	Scheduled Refurbishments per No. of Reuses		
					20	50	100
• Mono-Propellant - 25 lb Thrust	Indefinite	340 sec	4K sec	12	1	4	8
• Cryogenic - 25 lb Thrust	Indefinite	340 sec	9K sec	26	0	1	3

Note:

Refurbishment Criteria for Cryogenic ACPS was estimated at 50 percent of the operating life of a Category I RL-10 Main Engine before refurbishment. The RL-10 and the Cryogenic ACPS have similar components and wear life.

Table 11.7-21

ACPS REFURBISHMENT COSTS — STORABLE VS. CRYOGENIC

ACPS Candidates	Average Production Unit Cost $ K	Refurbishment as a % of Average Production Unit Cost	Cost per Refurbishment $ K	Missions before Scheduled Refurbishment	Scheduled Refurbishment Costs Per No. of Uses $ K		
					20	50	100
• Mono-Propellant - 25 Lb Thrust	861	1.1%	9.5 (1)	12	9.5	38	76
• Cryogenic - 25 Lb Thrust	1316.6	15%	197.5 (2)	26	-	197.5	592.5

Notes:

(1) Mono-Propellant ACPS refurbishment costs include only four axial (aft firing) thrusters.

(2) Cryogenic ACPS refurbishment costs include only the two primary turbomachinery/gas generator packages.

11.7.1 Maintenance Levels/Planning

The MDAC Space Tug Maintenance ($\bar{M}$) Refurbishment ($\bar{R}$) Concept minimizes $\bar{M}/\bar{R}$ requirements while maintaining a satisfactory degree of launch on time probability together with the required level of subsystem reliability to assure missions success. It is patterned after the commercial airlines "On Condition Maintenance" philosophy which monitors subsystem health and thus precludes unwarranted maintenance and refurbishment on subsystems, assemblies, and components which are functioning properly. Subsystem health is monitored by a combination of the following techniques:

a. Operational instrumentation data consisting of subsystem performance measurements which are telemetered during flight via ground link.

b. When the Tug is out of range of a ground tracking station, these data are recorded on board for later transmission.

c. Post Flight/Receiving Inspection

d. Automated subsystem checkout (ground) of those performance characteristics not readily adaptable to inflight monitoring.

e. Use of onboard checkout capability for fault detection and isolation.

Fundamental to this concept is the definition of subsystem line replaceable units (LRUs) to the lowest feasible level and the ability to fault isolate to that level. The basic repair philosophy is the replacement of LRUs and requires a maintenance/refurbishment analysis that considers repair vs throwaway and the optimum level of repair of LRUs. A system of rotable spares will be employed whereby a faulty LRU is replaced at the launch site with a servicable item from the spares inventory. The faulty item, if repairable, is returned to the factory/depot for repair and is then rotated back to the launch site inventory. This approach combines Bench/Shop Maintenance and Depot Maintenance thus eliminating redundancies in high dollar value GSE. The factory/depot repair schedule is made responsive to launch site operations requirements.

The Maintenance/Refurbishment ($\bar{M}/\bar{R}$) technical approach/methodology is not sensitive to individual Tug configurations; however, the cost of an $\bar{M}/\bar{R}$ cycle and depot maintenance will vary with different configurations. These variations have been expressed in the $\bar{M}/\bar{R}$ inputs to the cost model for each configuration in terms of Manhours/($\bar{M}/\bar{R}$) cycle, equivalent units of production hardware for operational spares and depot maintenance cost as a percentage of average subsystem hardware cost.

The definition of maintenance levels, maintenance planning methodology and the development process for maintenance procedures and a complete maintenance program is contained in Appendix B.

11.7.2 Impact on Turnaround Cycle

The failures risk analysis and spares planning data discussed in Section 6.11.4.1 have provided unscheduled maintenance predictions and indications of the magnitude of launch risk.

Table 11.7-22 shows the unscheduled maintenance man hours (MMH) expected as an average for a Tug turnaround cycle. These man hours are for LRU replacement and checkout in the Tug when the work is done in the normal maintenance and refurbishment cycle. The down time is a function of manloading by the particular skills required. The use of highly reliable space qualified hardware and proper qualification testing is essential to achieving a Tug design with this low maintenance man hour capability. Figure 11.7-1 shows a probability distribution for this unscheduled maintenance. The 90th percentile value indicates the total MMH expected not to be exceeded more frequently than 10 out of 100 maintenance and refurbishment cycles.

Predictions have been made for the risk of an anomaly occurring in the Tug equipment during the period of integrated systems test and servicing prior to Shuttle liftoff. (Ref. functions 2.1.7 through 2.4.4 as shown in FFD, Section 11.3.3). The total risk for each subsystem was divided into unreliability (risk of liftoff with a degraded component) and risk of pad loadout. The Tug risk of pad loadout is a function of subsystem verification capability (risk of failure x % testable). The risk of pad loadout prediction is 5 per 100 launches. The peak risk period is during Tug servicing, resulting from the operational stresses applied to instrumentation, fluid systems and activation of subsystem equipment just prior to launch.

The unreliability at launch prediction is * probability, * unreliable Tugs per 1000 launches. This risk represents the share of prelaunch anomalies present which are not detectable by the verification process. This low value represents the high verification capability expected from the combined Tug and Orbiter.

A trade study was conducted to estimate the effect of reduced maintenance time on these predicted performance values. An evaluation was made for each

*Options 1 and 3I only. Unreliability is 0.010 probability, 10 Tugs per 100 launches for Options 2 and 3F.

Duration 1-1/2 Days — MAINTAINABILITY ANALYSIS — TUG REPAIR COSTS — By Downs

Configuration 3I

Date 8-29-73
Rev. 9-3-73

Subsystems/Elements	Option for Configuration	System Test/Verification Post Flight Post M&R & Preflight — Location 1.1.6	1.1.7	1.2.1	2.3.9	2.4.2	2.4.3	Corrective Maintenance — Repr/Flt.	MMH/Rep.	MMH/Flight/Location — Structural 1.1.11	Propulsion 1.1.12	Avionics 1.1.13	Notes
Structure													
Fuel Tank								0.030	30	0.9			
Oxidizer Tank								0.030	30	0.9			
Tank Support								--					
Body Structure								0.050	30	1.5			
Thrust Structure								0.010	20	0.2			
Meteoroid Barrier								0.100	30	3.0			
Payload Interface								0.030	5	0.2			
Thermal Control	Paint							0.03	20	0.6			
Purge	Bag							0.031	10	0.3			
Avionics/Power													
Data Management and Instrumentation								0.221	10			2.21	
GNC								0.076	8			0.61	
Communications	A							0.066	6			0.40	
Electrical Power	Batt.							0.051	6			0.31	
Power Distribution and Control	El/Mech.							0.050	20			1.00	
Propulsion													
Main Engine	I, RL10							0.034	10		0.34		
Support													
Feed	1							0.005	10		0.05		
Fuel and Drain	1							0.007	10		0.07		
Pressurization	Amb. He							0.005	6		0.03		
Vent	1							0.014	4		0.06		
Pneumatic	From Press.							0.017	6		0.10		
Propellant Utilization	?							0.005	6		0.03		
TVC	Trident							0.001	4		0.01		
Orientation													
Feedline Conditioning													
ACPS Engine and Support	Blowdown N2H4							0.007	8		0.06		
	Total — Structure							0.25		6.7			
	TCS							0.061		0.9			
	Avionics							0.465				4.53	
	Propulsion							0.095			0.75		
	Total Repairs and MMH/Flt.							0.871			12.88		

Table 11.7-22 (Sheet 1 of 2)

Duration 6 Days — MAINTAINABILITY ANALYSIS — TUG REPAIR COSTS — By Downs

Configuration 3F

Date 8-30-73
Rev. 9-3-73

Subsystems/Elements	Option for Configuration	System Test/Verification Post Flight Post M&R & Preflight — Location 1.1.6	1.1.7	1.2.1	2.3.9	2.4.2	2.4.3	Corrective Maintenance — Repr/Flt.	MMH/Rep.	MMH/Flight/Location — Structural 1.1.11	Propulsion 1.1.12	Avionics 1.1.13	Notes
Structure													
Fuel Tank								0.040	30	1.20			
Oxidizer Tank								0.040	30	1.20			
Tank Support													
Body Structure								0.065	30	1.95			
Thrust Structure								0.013	20	0.26			
Meteoroid Barrier								0.130	30	0.39			
Payload Interface	Ret. & Spin							0.034	10	0.34			
Thermal Control	MLI							0.030	50	1.50			
Purge	Bag							0.066	10	0.66			
Avionics/Power													
Data Management and Instrumentation								0.946	10			9.46	
GNC								0.547	8			4.38	
Communications	A/C							0.237	6			1.42	
Electrical Power	3A3 -							0.060	6			0.36	
Power Distribution and Control	Semi Cond.							0.008	20			0.16	
Propulsion													
Main Engine	I, RL10							0.034	10		0.34		
Support													
Feed	1							0.012	10		0.12		
Fill and Drain	1							0.018	10		0.18		
Pressurization	Cold He							0.067	10		0.67		
Vent	1							0.048	4		0.19		
Pneumatic	1							0.041	6		0.25		
Propellant Utilization	2							0.012	6		0.07		
TVC	Trident							0.001	4		0.01		
Orientation													
Feedline Conditioning													
ACPS Engine and Support	Storable Biprop.							0.146	8		1.17		
	Total — Structure							0.322		5.34			
	TCS							0.096		2.16			
	Avionics							1.798				15.78	
	Propulsion							0.379			3.00		
	Total Repairs and MMH/Flt.							2.595			26.28		

Table II-22 (Sheet 2 of 2)

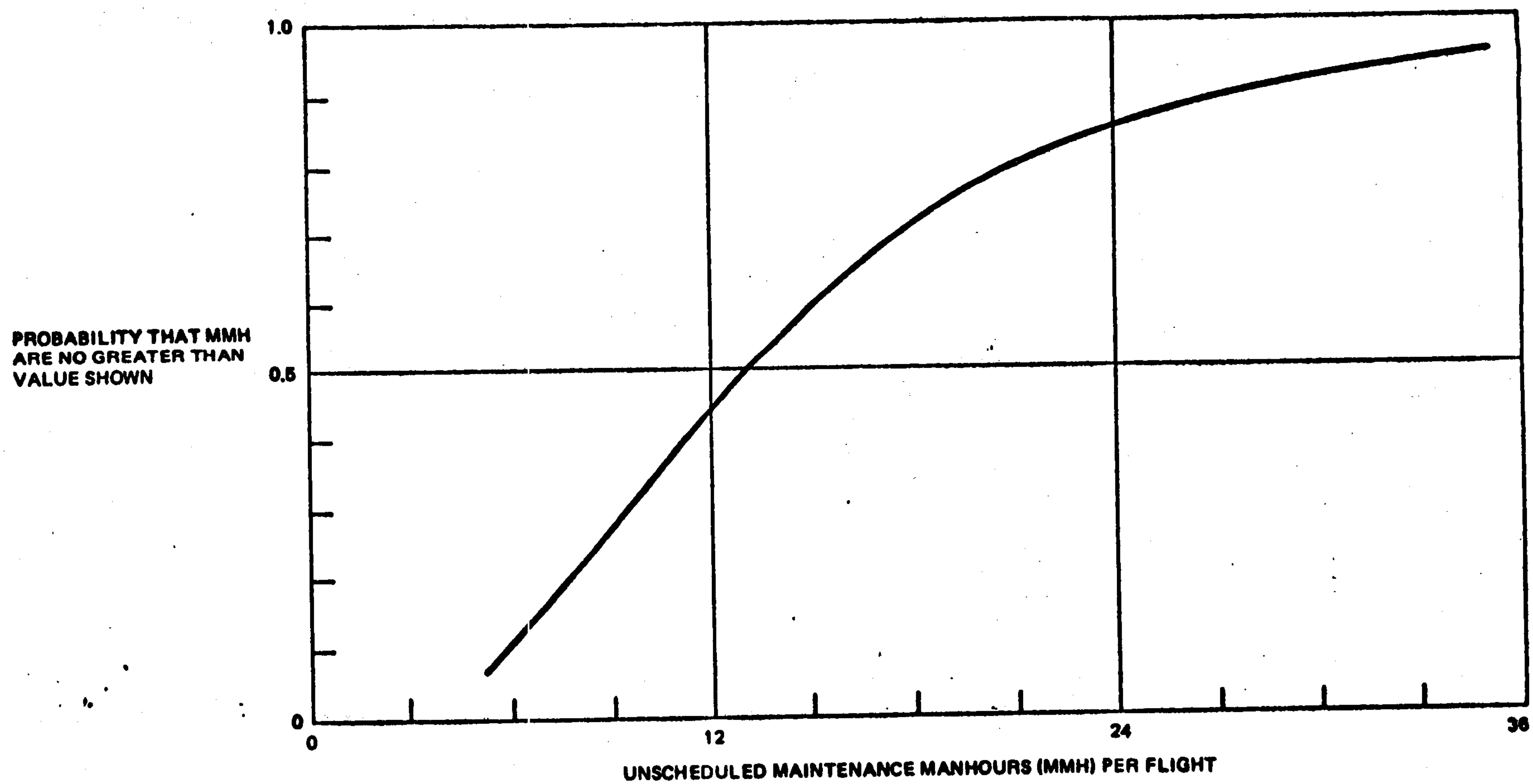


Figure 11.7-1. Probability Distribution – Unscheduled Maintenance Manhours per Flight (Options 1 & 3I)

(Sheet 1 of 2)

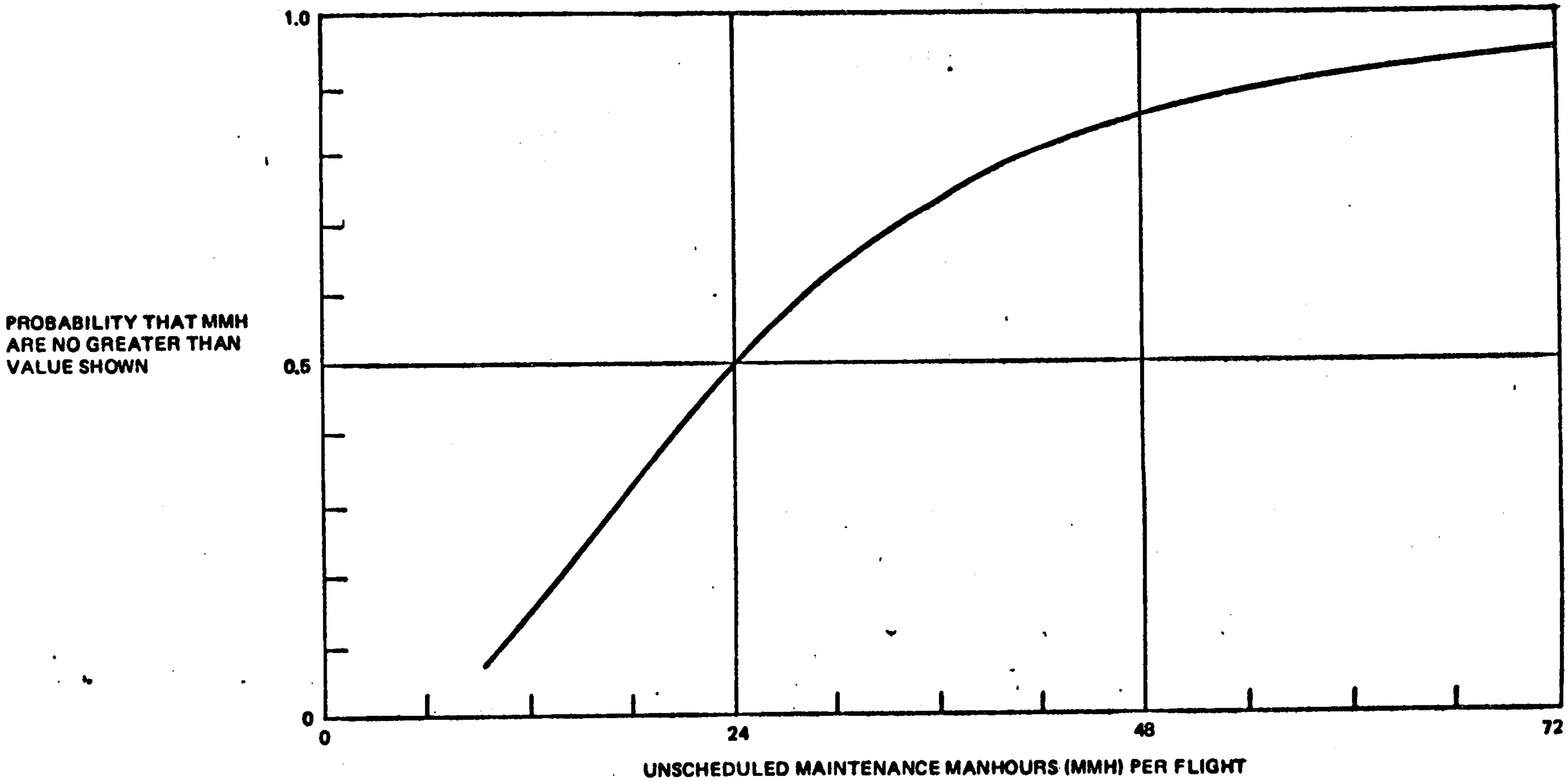


Figure ~~6.11.7.A~~ 11.7-1 Probability Distribution – Unscheduled Maintenance Manhours per Flight (Options 2 & 3F)

(Sheet 2 of 2)

function to estimate the effect of reducing test hours which in effect would reduce the probability of finding faulty equipment early in the maintenance and refurbishment cycle. The functions, total times and minimum considered potentially feasible are shown in Table 11.7-23. In each case the results of time reduction in one function was evaluated for its effect on later functions. With these reductions it is estimated to increase risks of pad loadout by 24% and launch unreliability fivefold.

The increase to almost five unreliable Tugs per 100 flights indicates that a serioud man hour reduction (31%) is not cost effective. Careful analysis during design development may determine cost savings available in test time or equipment utilization to provide cost savings without increasing unreliability.

Table 11.7-23

MAINTENANCE TEST & VERIFICATION OPERATIONS BY FUNCTION

FUNCTION	1.1.6 Post Flt.	1.1.7 Subs. %		1.2.1 Post M & R	2.2.1.3/2.2.4 Verify Tug To S/C 1/F	2.3.9 Verify P/L to ORB 1/F	OAT 2.4.1 Orbiter & P/L IST	Total Test & Verif.	
OPERATION & TIME (MMH)									
AVIONICS		127.5							
PROPULSION									
AMB. He (1&3I)		40.0							
Zero NPSH (2)		40.0							
Cold Ne (3F)		42.5							
ACPS									
MONO - Blowdn (3I)		35.0							
- Pressure (1)		65.0							
Bl PROP (2,3F)		65.0							
TOTAL	92	(I) 232.5		8	23 or 38	115	128	613.5	1
		(2) 232.5						613.5	2
		(3I) 202.5						583.5	3I
		(3F) 235.0						616.0	3F
REDUCE TO Minimum	40	70	Avionics	8	23 or 38	80	80	371	1
		55	Propulsion						
							Reduction	242.5	(31%)

11.7.3 Effect on Logistics

The Logistics technical approach/methodology is not sensitive to individual Tug configurations; however, the costs associated with the dollar value of a logistics inventory will vary with the design complexity of different configurations. The transportation costs are indirectly influenced by configuration, but only as a function of fleet size. The training and inventory control and warehousing functions are relatively insensitive to configuration differences. Variations in dollar value of the logistics inventory have been expressed in the Maintenance and Refurbishment inputs to the cost model.

11.7.4 Tug/Payload Integrated Checkout

The Tug/Payload Integrated Checkout will be performed as follows at the locations indicated.

TPF

1. Connect payload simulator to Tug and verify wiring and electrical load inputs using Tug Data Management System.

PPF/TPF

1. Perform continuity check on Tug prior to mating with payload.
2. Mate payload with Tug.
3. Radiate payload through Ground Telemetry Station and readout telemetry.

MCF

1. Check electrical interface between Shuttle and Tug payload.
2. Load software into Mission Payload Specialist's console.
3. Perform integrated systems test with payload, Tug and Shuttle all in the loop.
4. Radiate telemetry to Ground TM Station via either open or closed loop and readout telemetry.

11.7.5 Onboard vs Ground Checkout — Program Option 1 and 3I

SUMMARY

Onboard checkout is cost effective, even though the operations benefits are zero, the large manpower required due to the large manpower requirements necessary to support the Tug/Shuttle function at the launch sites. If the Shuttle/Tug functions weren't a constraint, there would be an even greater savings due to the additional personnel required at each TPF and launch site to operate the additional GSE.

Other advantages of onboard checkout not reflected in the cost estimates include:

a. Ground and mission flexibility and reduced Tug dependence on the Shuttle.
b. Less cost impact to changes (ECP's) that affect the Tug vehicle and which would further result in changing all sets of GSE.

The GSE description sheets define the additional GSE required and their associated costs which total $9.654M of which 3.08 is additional DDT&E cost.

The vehicle cost consists of developing a self-checkout capability in the Star Tracker, additional wiring and the addition of (4) RMU's. The Built-In Test Equipment consists of self check capability in the Signal Conditioning Unit, Response Unit and Remote Multiplexer and a manual self-check capability in the Data Control Unit and System Control Unit. Additional checkout software are also required.

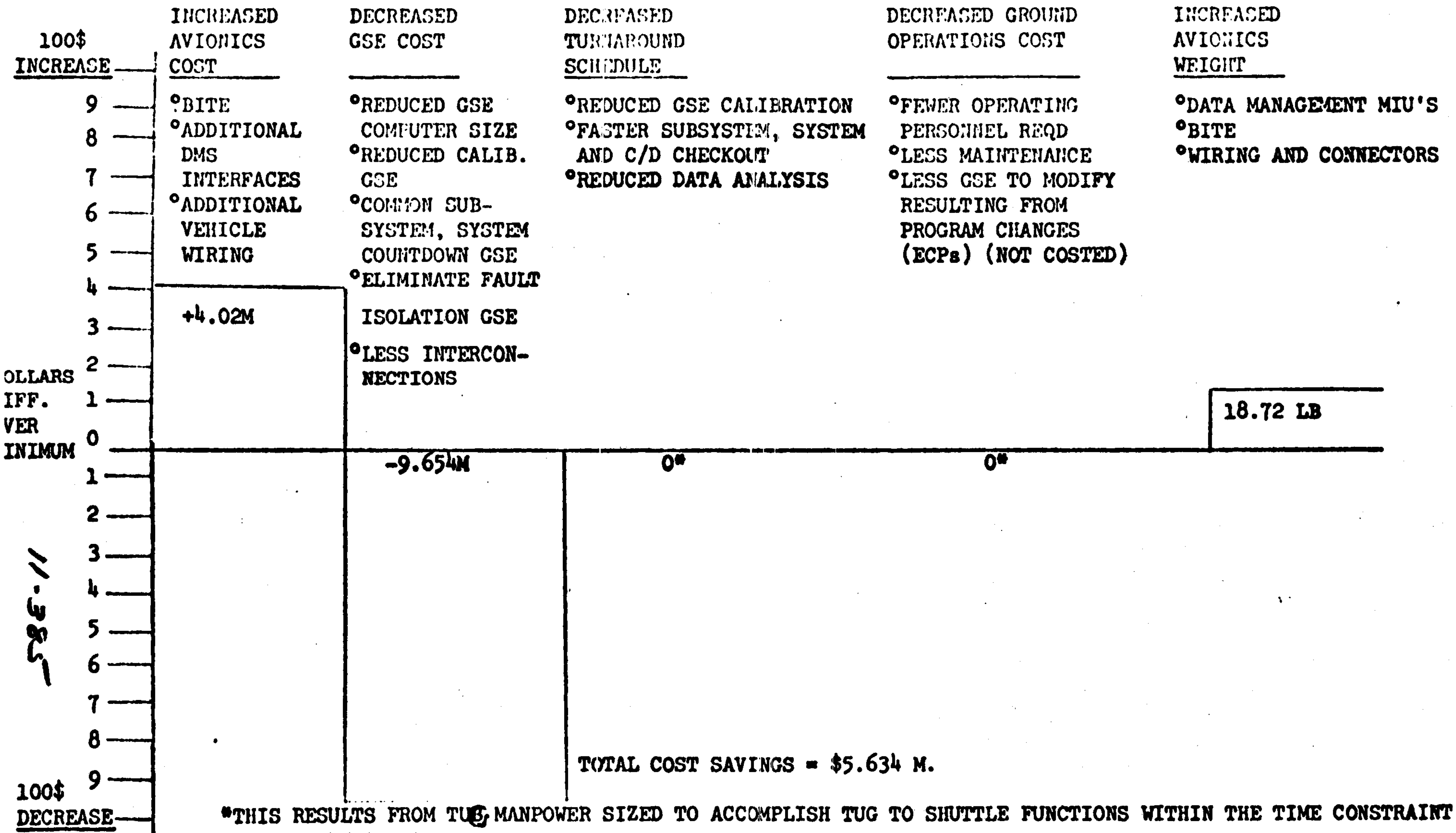
The MDAC onboard checkout philosophy utilizes the vehicle DMS system and checkout software to perform functional vehicle checkout and fault isolation to the LRU level with minimal GSE support. The onboard checkout capability is achieved through a combination of built-in/centralized test equipment. The DMS requires access to those parameters required to support inflight redundancy management. In flight redundancy management refers to the process of fault detection and isolation to the level at which redundant components can be switched. "Checkout only" parameters are those required to fault isolate to the LRU level. The definition of "checkout only" parameters is a function of the actual flight software logic and is therefore rather subjective at this time. The "checkout only" parameters would also be available in flight but software is not included in our estimate to perform in flight fault isolation to an LRU level unless required to support redundancy management.

The degree of built in versus centralized versus ground test equipment is dictated primarily by existing designs, feasibility, effect on reliability, and development cost.

The increase in vehicle cost is due primarily to the development of BITE particularly in the DMS which is a new design. The cost of additional interface channels is negligible since these units must be developed in any case and the parameters normally exist on test connectors although some additional signal conditioning may be required.

The increase in weight is due to the additional DMS interface units required less the additional wire required to route the checkout parameters to these connectors panels. (NOTE: Test connector panels may not be required for some electronics boxes since access to the box test connector may be available in the forward skirt.)

IMPACT OF FULL ON   RD CHECKOUT



*THIS RESULTS FROM TUG MANPOWER SIZED TO ACCOMPLISH TUG TO SHUTTLE FUNCTIONS WITHIN THE TIME CONSTRAINT IMPOSED BY SHUTTLE.

CONSLUSION: 1. ONBOARD CHECKOUT IS COST EFFECTIVE WITH ONLY SLIGHT INCREASE IN VEHICLE COST WITH A REDUCTION IN GSE COST.

2. ONBOARD CHECKOUT PROVIDE GROUND AND MISSION FLEXIBILITY AND REDUCES SHUTTLE DEPENDENCE.

GSE DESCRIPTION SHEET

NAME: COMMAND RESPONSE UNIT EQUIPMENT NO. ________

FUNCTIONAL REQUIREMENT(S):

This unit shall generate hardline stimuli for testing Tug hardware and will be able to transfer Tug signals from the Tug to the digital portion of the GSE checkout system.

EQUIPMENT DESCRIPTION:

This unit is composed of 2 SCUs, 8 PCUs, 2 DCUs, 16 RMUs, 40 connectors, terminal board assemblies, and 9500 wire terminations. Similar to DSV-4B-130.

$ 1,050,000 (DEVELOPMENT COST)

$ 230,000 (UNIT COST)

EQUIPMENT CATEGORY:

NEW X MODIFIED ______ AS IS 50% of DSV-4B-130

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
	ETR (TPF)	1
	ETR (LAUNCH PAD)	1
	ETR (LAUNCH PAD)	1
	WTR (TPF)	1
	WTR (LAUNCH PAD)	1
	FACTORY	1

TOTAL REQUIRED 6 TOTAL COST $ 2,430,000

GSE DESCRIPTION SHEET

NAME: GROUND EQUIPMENT TEST SET EQUIPMENT NO. ______

FUNCTIONAL REQUIREMENT(S):

The Ground Equipment Test Set shall provide an overall check of the GSE system when the Tug is not connected. The test set shall verify the satisfactory operation of that portion of the GSE not verified by self test programs.

EQUIPMENT DESCRIPTION:

1 patch panel (1000 pts), 35 connectors, test point panel (200 TP), terminal board assemblies and 8500 wire terminations similar to DSV-4B-132.

$ 1,660,000 (DEVELOPMENT COST)

$ 373,000 (UNIT COST)

EQUIPMENT CATEGORY:

NEW x MODIFIED ______ AS IS 30% of DSV-4B-132

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
	ETR (LAUNCH PAD)	1
	ETR (LAUNCH PAD)	1
	WTR (TPF)	1
	WTR (TPF)	1
	WTR (LAUNCH PAD)	1
	FACTORY	1

TOTAL REQUIRED 6 TOTAL COST $ 3,898,000

GSE DESCRIPTION SHEET

NAME: INTERFACE JUNCTION BOX EQUIPMENT NO. ______

FUNCTIONAL REQUIREMENT(S):

This unit provides vehicle circuit protection and the patching interface between the Tug and the GSE.

EQUIPMENT DESCRIPTION:

Two bay junction box consisting of test point panels, fuse and circuit breaker panels, patch panels, and terminal boards. Similar to DSV-7-100A3.

$ 350,000 (DEVELOPMENT COST)

$ 293,000 (UNIT COST)

EQUIPMENT CATEGORY:

NEW X MODIFIED ______ AS IS 30% of DSV-7-100

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
	ETR (LAUNCH PAD)	1
	ETR (LAUNCH PAD)	1
	ETR (TPF)	1
	WTR (TPF)	1
	WTR (LAUNCH PAD)	1
	FACTORY	1

TOTAL REQUIRED ______ TOTAL COST $ 3,108,000

GSE DESCRIPTION SHEET

NAME: CABLE NETWORK KIT EQUIPMENT NO. ____

FUNCTIONAL REQUIREMENT(S):

This kit will provide all electrical interconnect cables for connection of the Tug umbilical and black box test connectors to the interface junction box and for connection of the junction box to the Tug checkout GSE.

EQUIPMENT DESCRIPTION:

This unit is composed of the following cable types: 5 four pin power cables, thirty 60 pin cables, and five 39 pin cables.

$ 20,000 (DEVELOPMENT COST)

$ 23,000 (UNIT COST)

EQUIPMENT CATEGORY:

NEW X MODIFIED ____ AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
	ETR (TPF)	1
	ETR (LAUNCH PAD)	1
	ETR (LAUNCH PAD)	1
	WTR (TPF)	1
	WTR (LAUNCH PAD)	1
	FACTORY	1

TOTAL REQUIRED 6 TOTAL COST $ 218,000

11.7.5 Onboard vs Ground Checkout -- Program Option 2 and 3F

Onboard checkout is cost effective, even though the operations benefits are zero, due to the large manpower requirements necessary to support the Tug/Shuttle function at the launch sites. If the Shuttle/Tug functions weren't a constraint, there would be an even greater savings due to the additional personnel required at each TPF and launch site to operate the additional GSE.

Other advantages of onboard checkout not reflected in the cost estimates include:

a. Ground and mission flexibility and reduced Tug dependence on the Shuttle.

b. Less cost impact to changes (ECP's) that affect the Tug vehicle and which would further result in changing all sets of GSE.

The GSE description sheets define the additional GSE required and their associated costs which total $12.872M of which 4.10 is additional DDT&E cost.

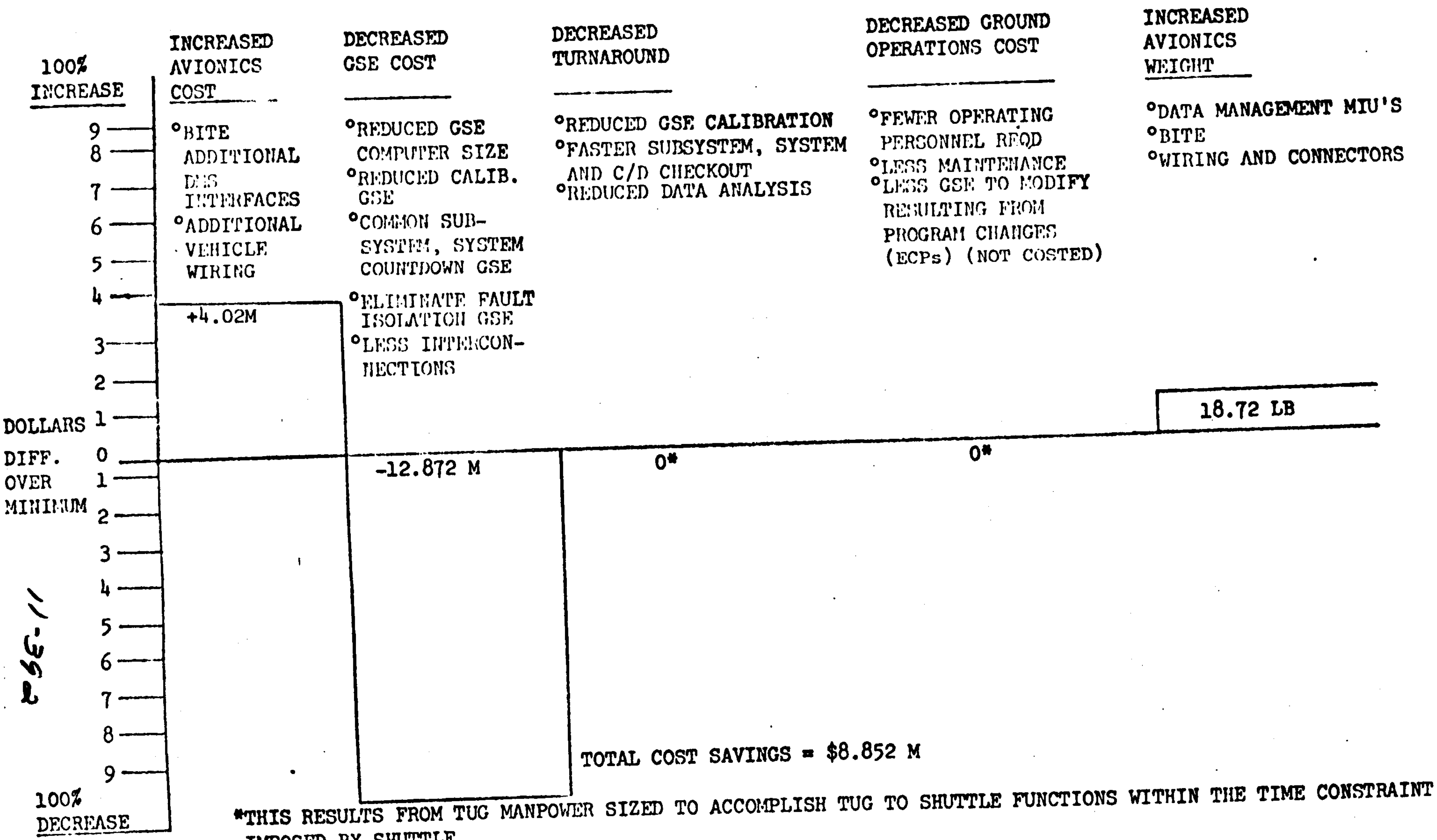
The vehicle cost consists of developing a self-checkout capability in the Star Tracker, additional wiring and the addition of (4) RMU's. The Built-In Test Equipment consists of a self check capability in the Signal Conditioning Unit, Response Unit and Remote Multiplexer, and a manual self-check capability in the Data Control Unit and System Control Unit. Additional checkout software are also required.

The MDAC onboard checkout philosophy utilizes the vehicle DMS system and checkout software to perform functional vehicle checkout and fault isolation to the LRU level with minimal GSE support. The onboard checkout capability is achieved through a combination of built-in/centralized test equipment. The DMS requires access to those parameters required to support inflight redundancy management. In flight redundancy management refers to the process of fault detection and isolation to the level at which redundant components can be switched. "Checkout only" parameters are those required to fault isolate to the LRU level. The definition of "checkout only" parameters is a function of the actual flight software logic and is therefore rather subjective at this time. The "checkout only" parameters would also be available in flight but software is not included in our estimate to perform in flight fault isolation to an LRU level unless required to support redundancy management.

The degree of built-in versus centralized versus ground test equipment is dictated primarily by existing designs, feasibility, effect on reliability, and development cost.

The increase in vehicle cost is due primarily to the development of BITE particularly in the DMS which is a new design. The cost of additional interface channels is negligible since these units must be developed in any case and the parameters normally exist on test connectors although some additional signal conditioning may be required.

The increase in weight is due to the additional DMS interface units required less the additional wire required to route the checkout parameters to these connectors panels. (NOTE: Test connector panels may not be required for some electronics boxes since access to the box test connector may be available in the forward skirt.)



*THIS RESULTS FROM TUG MANPOWER SIZED TO ACCOMPLISH TUG TO SHUTTLE FUNCTIONS WITHIN THE TIME CONSTRAINT IMPOSED BY SHUTTLE.

CONCLUSION:

1. ONBOARD CHECKOUT IS COST EFFECTIVE WITH ONLY SLIGHT INCREASE IN VEHICLE COST WITH A REDUCTION IN GSE COST.
2. ONBOARD CHECKOUT PROVIDE GROUND AND MISSION FLEXIBILITY AND REDUCES SHUTTLE DEPENDENCE.

GSE DESCRIPTION SHEET

NAME: COMMAND RESPONSE UNIT EQUIPMENT NO. ________

FUNCTIONAL REQUIREMENT(S):

This unit shall generate hardline stimuli for testing Tug hardware and will be able to transfer Tug signals from the Tug to the digital portion of the GSE checkout system.

EQUIPMENT DESCRIPTION:

This unit is composed of 2 SCUs, 8 PCUs, 2 DCUs, 16 RMUs, 40 connectors, terminal board assemblies, and 9500 wire terminations. Similar to DSV-4B-130.

$ 1,399,650 (DEVELOPMENT COST)

$ 306,590 (UNIT COST)

EQUIPMENT CATEGORY:

NEW X MODIFIED ______ AS IS 50% of DSV-4B-130

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
	ETR (TPF)	1
	ETR (LAUNCH PAD)	1
	ETR (LAUNCH PAD)	1
	WTR (TPF)	1
	WTR (LAUNCH PAD)	1
	FACTORY	1

TOTAL REQUIRED 6 TOTAL COST $ 3,239,190

GSE DESCRIPTION SHEET

NAME: GROUND EQUIPMENT TEST SET EQUIPMENT NO. ____________

FUNCTIONAL REQUIREMENT(S):

The Ground Equipment Test Set shall provide an overall check of the GSE system when the Tug is not connected. The test set shall verify the satisfactory operation of that portion of the GSE not verified by self test programs.

EQUIPMENT DESCRIPTION:

1 patch panel (1000 pts), 35 connectors, test point panel (200 TP), terminal board assemblies and 8500 wire terminations similar to DSV-4B-132.

$ 2,212,780 (DEVELOPMENT COST)

$ 497,209 (UNIT COST)

EQUIPMENT CATEGORY:

NEW X MODIFIED ____ AS IS 30% of DSV-4B-132

1ST YEAR REQ'D ____________ NUMBER AVAILABLE ____________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
	ETR (LAUNCH PAD)	1
	ETR (LAUNCH PAD)	1
	WTR (TPF)	1
	WTR (TPF)	1
	WTR (LAUNCH PAD)	1
	FACTORY	1

TOTAL REQUIRED ____________ TOTAL COST $ 5,196,034

GSE DESCRIPTION SHEET

NAME: INTERFACE JUNCTION BOX EQUIPMENT NO. ______

FUNCTIONAL REQUIREMENT(S):

This unit provides vehicle circuit protection and the patching interface between the Tug and the GSE.

EQUIPMENT DESCRIPTION:

Two bay junction box consisting of test point panels, fuse and circuit breaker panels, patch panels, and terminal boards. Similar to DSV-7-100A3.

$ 466,550 (DEVELOPMENT COST)

$ 390,569 (UNIT COST)

EQUIPMENT CATEGORY:

NEW X MODIFIED ______ AS IS ______

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
	ETR (LAUNCH PAD)	1
	ETR (LAUNCH PAD)	1
	ETR (TPF)	1
	WTR (TPF)	1
	WTR (LAUNCH PAD)	
	FACTORY	1

TOTAL REQUIRED 6 TOTAL COST $ 2,809,964

GSE DESCRIPTION SHEET

NAME: CABLE NETWORK KIT EQUIPMENT NO. ____________

FUNCTIONAL REQUIREMENT(S):

This kit will provide all electrical interconnect cables for connection of the Tug umbilical and black box test connectors to the interface junction box and for connection of the junction box to the Tug checkout GSE.

EQUIPMENT DESCRIPTION:

This unit is composed of the following cable types: 5 four pin power cables, thirty 60 pin cables, and five 39 pin cables.

$ 106,640 (DEVELOPMENT COST)

$ 30,659 (UNIT COST)

EQUIPMENT CATEGORY:

NEW X MODIFIED ____ AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
	ETR (TPF)	1
	ETR (LAUNCH PAD)	1
	ETR (LAUNCH PAD)	1
	WTR (TPF)	1
	WTR (LAUNCH PAD)	1
	FACTORY	1

TOTAL REQUIRED 6 TOTAL COST $ 290,554

11.8 TUG FLEET SIZE

11.8.1 Active Tug Fleet Size

The Active Tug Fleet size is summarized in Figure 8.11.1-1 and 8.11.1-2.

11.8.2 Total Program Fleet Size

The Tug fleet sizing analysis was based upon the flight schedule developed as a result of the mission accomplishment analysis (as reported in Volume 4). The capture analysis identified the flight by flight mission accomplishment. With the flight schedule and associated flight mode and the effect of reliability, the fleet size necessary to carry out the activity was developed.

The total program fleet size is 13 vehicles of which 2 must be available in the year of IOC.

11.8.3 Factors Influencing Fleet Size

Table 11-1 shows the schedule of flights per year by Tug I.D. number. At the top of the chart, the number of flights per year is shown and the number of Tug expendable flights. The number of Tugs required were established by first determining the number of Tugs necessary to accomplish the 1990 requirements and working backward from that point to 1984. The maximum number of

TUG ACTIVE FLEET SIZE

OPTION 3I

ETR

	YEAR										
	80	81	82	83	84	85	86	87	88	89	90
NO. OF TUGS	1	2	2	3	2	2	2	1	0	0	0

WTR

	YEAR										
	80	81	82	83	84	85	86	87	88	89	90
NO. OF TUGS	0	0	0	1	0	0	0	0	0	0	0

OPTION 3I 2 YR. IOC DELAY

ETR

	YEAR										
	80	81	82	83	84	85	86	87	88	89	90
NO. OF TUGS	0	0	2	3	2	2	2	1	0	0	0

WTR

	YEAR										
	80	81	82	83	84	85	86	87	88	89	90
NO. OF TUGS	0	0	0	1	0	0	0	0	0	0	0

FIGURE 8.11.1-1

TUG ACTIVE FLEET SIZE

OPTION 3F

ETR	YEAR										
	80	81	82	83	84	85	86	87	88	89	90
NO. OF TUGS	0	0	0	0	2	2	2	3	4	3	3

WTR	YEAR										
	80	81	82	83	84	85	86	87	88	89	90
NO. OF TUGS	0	0	0	0	1	1	1	1	1	1	1

OPTION 3F 2 YR. IOC DELAY

ETR	YEAR										
	80	81	82	83	84	85	86	87	88	89	90
NO. OF TUGS	0	0	0	0	2	2	2	3	4	3	3

WTR	YEAR										
	80	81	82	83	84	85	86	87	88	89	90
NO. OF TUGS	0	0	0	0	1	1	1	1	1	1	1

FIG. 8.11.1-2

TABLE 11 -1

EQUAL USAGE SCHEDULE

OPTION 3

	80	81	82	83	84	85	86	87	88	89	90	TOTAL
NUMBER OF FLIGHTS	3	21	22	36	44	41	41	40	37	41	40	366
NUMBER OF EXPENDED TUGS					2		1			3	1	8
TUG ID 1	2	9	7	10	4							32
2	1	8	9	10	4							32
3		4	2	10	5	7	5					33
4			4	6	4	6	8	5				33
5					9	8	6	4	4	2		33
6					9	8	6	4	4	2		33
7					9	8	6	4	4	2		33
8						4	6	10	2	5	6	33
9							4	10	3	10	6	33
10								3	10	10	10	33
11									10	5	9	24
12										5	9	14
[illegible]												

flights any Tug can perform in a year is established first by summing the Tug ground turnaround time and the mission time which results in the minimum mission turnaround time. In Option 3 the ground turnaround time is as follows:

Configuration	Ground Turn-around Time (Days)	Average Mission Time (Days)	Average Mission Turnaround Time (Days)
Initial	28.0	1.7	29.7
Final	29.0	3.3	32.3

Using this number and assuming that the maximum number of flights that an expended Tug can make in the year that it is expended is 6 (one-half the maximum turnaround in a year), the fleet of 5 for 1990 is established. Working backward from there it can be seen that in 1989 the three expendable requirements and the necessary vehicles used in 1990 make up the inventory requirements. In 1984 the initial Tug flights are limited by its capabilities (it is able to perform only 17 of the 44 flights) thus the final configuration initial year fleet is established to accomplish the remaining flights. The initial Tug fleet size of 4 is established by the 1983 requirement of 36 flights.

The resulting data show that to carry out the operations a total of 12 Tugs is required of which 4 are initial and 8 are final configurations.

Using the Government ground rules for reliability losses, 4 additional vehicles are required (1 initial and 3 final configurations). Thus the total fleet size necessary is 16 of which 2 initial configurations are required at IOC (1980) and 4 final configurations at IOC (1984).

The major influence on fleet sizing is the number of expendable Tug missions required. If, for example, no expendable missions were required the required fleet size could be reduced to nine vehicles including reliability losses (4 initial and 5 final vehicles).

11.9 COST DATA

The ground operations have been analyzed and costed in two separate "breakouts" of the elements involved. The first breakout is the standard Work Breakdown Structure for the study, as defined by the Government and included in the cost analysis program. The second breakout is the "standard numbering system for tasks identified in the functional flow diagrams," as provided by the Government and included in all the ground and launch operations analyses conducted in the study. These two breakouts are correlated in Table 11.9-1 to indicate the MDAC approach to resolution of the apparent discontinuities between the two accounting methods.

The ground operations cost data are proviced on Table 11.9-2, as developed for both ETR and WTR (where applicable). These cost data are listed in agreement with the ground and launch operations numbering system and organization of Section 6.11 of this document, as shown on the left half of Table 11.9-1.

The costs presented are a direct function of ground crew size and the methodology employed to optimize manpower. Accordingly, to help substantiate the cost estimates, trade study sheets for Determination of Ground Crew Size and Innova-tion Ground Operations Techniques are included. These data are in response to action items 95 and 97.

TABLE 11.9-!

GROUND OPERATIONS CORRELATION

GROUND & LAUNCH OPS. NUMBER	WBS ELEMENT
1.1 MAINTENANCE	SCHEDULED M&R (320-13/14-01) UNSCHEDULED M&R (320-13/14-02) REFURBISHMNET PLNG (320-13/14-05)
1.2 POST-MAINTENANCE CHECKOUT	POST MAINT CHECKOUT (320-13/14-03)
2.1 TUB SYSTEM & INTEG SYS. C/O 2.2 SC/TUG MATE	TUG/PAYLOAD MATING & C/O (320-13/14-04)
2.3 SHUTTLE/TUG MATE	TUG/SHUTTLE MATING & C/O (320-09/10-02)
2.4 COUNTDOWN	PRELAUNCH CHECKOUT (320-09/10-03) COUNTDOWN (320-09/10-04)
3.1 SAFE AND SECURE 3.2 SHUTTLE/TUG DEMATE 3.3 SC/TUG DEMATE	POST FLIGHT SAFING (320-09/10-06)
GROUND SUPPORT EQUIP. ----------	---------- GROUND SUPPORT EQUIP. (320-07-02/03)
FACILITIES ----------	---------- ETR FACILITIES (320-06-03/04) WTR FACILITIES (320-06-05/06)
LOGISTICS ----------	---------- LOGISTICS (320-05)
DEPOT MAINTENANCE ----------	---------- DEPOT MAINTENANCE (320-13/14-06)

TABLE 11.9-2

3I GROUND OPERATIONS COST DATA

ELEMENT	COST IN $ MILLIONS	
	ETR	WTR
LOGISTICS	4.3	
DEPOT MAINTENANCE	18.2	1.9
MAINTENANCE	4.0	0.7
POST-MAINTENANCE CHECKOUT	0.1	0.05
TUG SYS C/O & SC/TUG MATE & C/O	2.2	0.4
SHUTTLE TUG MATE	1.4	0.2
COUNTDOWN	3.1	0.6
POST-FLIGHT OPERATIONS	1.9	0.3
GROUND SUPPORT EQUIPMENT	12.7	11.2
FACILITIES	2.2	1.6

TABLE 11.9-2 (cont.)

3F GROUND OPERATIONS COST DATA

ELEMENT	COST IN $ MILLIONS	
	ETR	WTR
LOGISTICS	8.2	
DEPOT MAINTENANCE	32.1	6.8
MAINTENANCE	11.0	4.7
POST-MAINTENANCE CHECKOUT	0.4	0.2
TUG SYS C/O & SC/TUG MATE & C/O	5.4	2.2
SHUTTLE TUG MATE	3.8	1.7
COUNTDOWN	13.1	5.0
POST-FLIGHT OPERATIONS	5.5	2.2
GROUND SUPPORT EQUIPMENT	2.3	1.4
FACILITIES	0	0

DETERMINATION OF GROUND CREW SIZE (ACTION ITEM 95)

The methodology of ground crew sizing for the cryogenic Tug basically consists of a ten step process. Each process step is described below and illustrated in Figure 1.

STEP 1: FUNCTIONAL FLOWS

For each Tug vehicle configuration option, top level functional flow diagrams were developed to reflect the operational requirements of the following items;

Flight Requirements (NASA/DOD)

- o ETR launch
- o WTR launches

Flight Composition

- o Tug (Basic)
- o Tug with Kick Stage

STEP 2: TASK DESCRIPTION SHEETS

For each function identified in the functional flow diagrams of Step 1, a task description sheet waw constructed. The title, objective, purpose, location, required equipment, manpower and interface requirements for each functional task is specified on these sheets and are a prerequisite to the development of timelines and manloading.

GROUND & LAUNCH OPERATIONS METHODOLOGY

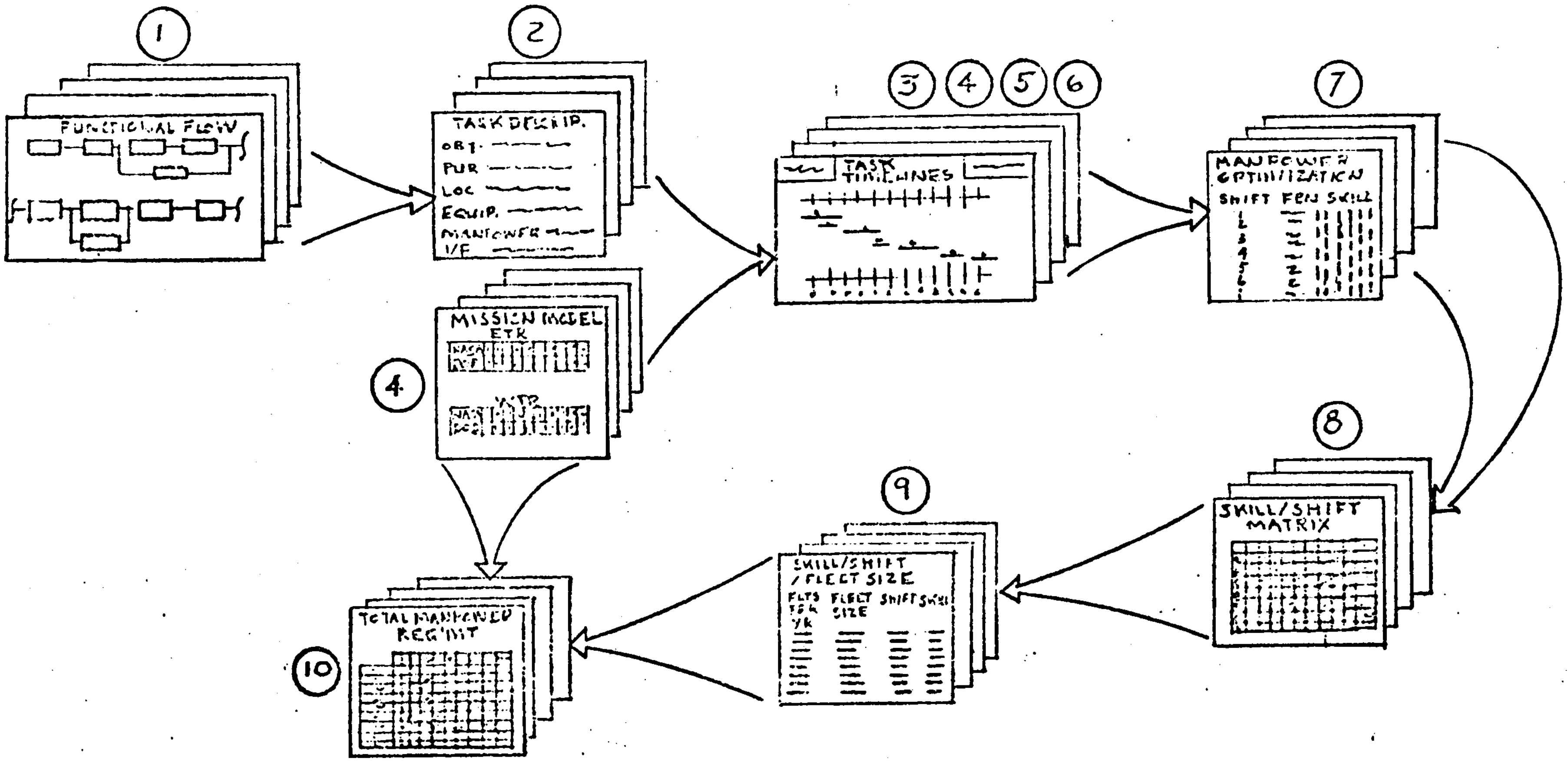


Figure 1

STEP 3: SUBTASK DEFINITION

Individual subtasks and their respective manpower allocation required to accomplish each functional task were defined utilizing the task description sheets of Step 2 and their timelines to determine the overall time required for each functional task.

STEP 4: MISSION MODEL ANALYSIS

The mission model for each Tug vehicle configuration option was analyzed for each launch site with regard to number of launches, user (NASA and DOD), flight composition, and mission type (deployment, round trip, etc.) The predominate Tug mission was then selected for detailed analysis and development of task timelines and sequences, and ground and launch operations manning requirements.

STEP 5: TASK TIMELINES AND SEQUENCE DEVELOPMENT

Based on the predominate Tug mission selected for each Tug vehicle configuration option in Step 4, the appropriate functional task timelines developed in Step 3 were assembled on a sequential hour by hour basis in a manner consistent with the functional flows for each respective Tug option.

STEP 6: TURNAROUND TIMES

Tug turnaround times were determined and top-level operational bar-chart flows were developed for each Tug configuration option based on the assembled timelines of Step 5.

STEP 7: SKILL PER SHIFT DETERMINATION

The task timelines of Step 5 were evaluated on a task per flight basis and appropriate manpower skill requirements were optimized utilizing skill sharing techniques where possible.

STEP 8: MAXIMUM vs. MANDATORY SKILL BREAKDOWN

A skill per shift matrix was developed for each Tug vehicle configuration option utilizing the data derived in Step 7 in order to determine the maximum skill breakdown requirements and the mandatory skill breakdown requirements during those shifts whose operations are constrained by the Orbiter ground processing schedule.

STEP 9: MANPOWER vs. FLEET SIZE DETERMINATION

Based on the required on-orbit time and the turnaround time derived in Step 6 for each Tug option, liftoff to liftoff times were determined and the active Tug fleet size for any required launch rate was derived. Manpower levels for each required skill were then assigned on a per-shift basis accordingly.

STEP 10:

Utilizing the data generated in Step 9 and the number of required launches per year as specified in the traffic model for each Tug option, a total manpower per skill per shift per year matrix was developed.

The crew size for each Tug option is attached.

TOTAL MANPOWER REQUIREMENTS

CONFIGURATION I

ETR	YEAR 80		81		82		83		84		85		86		87		88		89		90	
SHIFT	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
a	4	4	7	4	7	4	8	7	8	7	7	4	7	4	8	7	7	4	8	7	7	4
b	5	5	7	5	7	5	10	7	10	7	7	5	7	5	10	7	7	5	10	7	7	5
c	5	5	7	5	7	5	10	7	10	7	7	5	7	5	10	7	7	5	10	7	7	5
D	9	0	11	11	11	11	22	11	22	11	11	11	11	11	22	11	11	11	22	11	11	11
E	3	0	5	3	5	3	6	5	6	5	5	3	5	3	6	5	5	3	6	5	5	3
f.	2	0	2	2	2	2	4	2	4	2	2	2	2	2	4	2	2	2	4	2	2	2
G	17	13	26	17	26	17	34	26	34	26	26	17	26	17	34	26	26	17	36	26	26	17
1ST SHIFT	45		65		65		94		94		65		65		94		65		94		65	
2ND SHIFT		27		47		47		65		65		47		47		65		47		65		47
TOTAL	72		112		112		159		159		112		112		159		112		159		112	

a. Propulsion Technicians
b. Mechanical/Structural/Thermal Technicians
c. Avionics Technicians
d. Engineering
e. Quality Control
f. Safety
g. Other

TOTAL MANPOWER REQUIREMENTS

CONFIGURATION 1

WTR	80		81		82		83		84		85		86		87		88		89		90	
SHIFT	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
a							4	4	4	0	4	4	4	4	4	4	4	0	4	4	4	0
b							5	5	5	0	5	5	5	5	5	5	5	0	5	5	5	0
c							5	5	5	0	5	5	5	5	5	5	5	0	5	5	5	0
D							11	5	9	0	11	0	9	0	11	0	9	0	11	5	9	0
E							3	1	3	0	3	0	3	0	3	0	3	0	3	1	3	0
f.							2	1	2	0	2	0	2	0	2	0	2	0	2	1	2	0
G							20	18	20	0	20	16	18	16	20	16	20	0	20	18	20	0
1ST SHIFT							50		48		50		48		48		48		50		48	
2ND SHIFT								39		0		30		30		30		0		39		0
TOTAL							89		48		80		78		78		48		89		48	

a. Propulsion Technicians

b. Mechanical/Structural/Thermal Technicians

c. Avionics Technicians

d. Engineering

e. Quality Control

f. Safety

g. Other

TOTAL MANPOWER REQUIREMENTS

CONFIGURATION Z

ETR	80		81		82		83		84		85		86		87		88		89		90	
SHIFT	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
a									8	6	8	6	8	6	8	6	8	6	8	6	12	8
b									14	7	14	7	14	7	14	7	14	7	14	7	14	10
c									12	7	12	7	12	7	12	7	12	7	12	7	14	12
D									30	15	30	15	30	15	30	15	30	15	30	15	30	30
E									6	4	6	4	6	4	6	4	6	4	6	4	8	6
f.									4	3	4	3	4	3	4	3	4	3	4	3	6	4
G									38	27	38	27	38	27	38	27	38	27	38	27	54	38
1ST SHIFT									112		112		112		112		112		112		138	
2ND SHIFT										69		69		69		69		69		69		112
TOTAL									181		181		181		181		181		181		250	

a. Propulsion Technicians
b. Mechanical/Structural/Thermal Technicians
c. Avionics Technicians
d. Engineering
e. Quality Control
f. Safety
g. Other

TOTAL MANPOWER REQUIREMENTS

CONFIGURATION 2

WTR	YEAR 80		81		82		83		84		85		86		87		88		89		90	
SHIFT	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
a											4	4	5	4	4	4	4	4	5	4	4	4
b											5	5	10	5	5	5	5	5	10	5	5	5
c											6	6	8	6	6	6	6	6	8	6	6	6
D											15	0	15	15	15	7	15	0	15	15	7	0
E											3	0	5	3	3	1	3	0	5	3	3	0
f.											2	0	2	2	2	1	2	0	2	2	2	0
G											19	16	28	18	19	16	19	14	28	18	17	14
1ST SHIFT											54		73		54		54		73		44	
2ND SHIFT												40		53		40		29		53		29
TOTAL											94		126		94		83		126		73	

a. Propulsion Technicians
b. Mechanical/Structural/Thermal Technicians
c. Avionics Technicians
d. Engineering
e. Quality Control
f. Safety
g. Other

TOTAL MANPOWER REQUIREMENTS
CONFIGURATION 3I

ETR	80		81		82		83		84		85		86		87		88		89		90	
SHIFT	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
a	3	3	6	6	6	6	6	6														
b	9	9	18	9	18	9	18	9														
c	5	5	10	7	10	7	10	7														
d	9	0	22	11	22	11	22	11														
e	3	0	6	5	6	5	6	5														
f	2	0	4	2	4	2	4	2														
g	20	7	42	22	42	22	42	22														
1ST SHIFT	51		108		108		108															
2ND SHIFT		34		62		62		62														
TOTAL	85		170		170		170															

a. PROPULSION TECH.
b. MECH./STR./THERM. TECH.
c. AVIONICS TECH.
d. ENGINEERING
e. QUALITY CONTROL
f. SAFETY
g. OTHER

TOTAL MANPOWER REQUIREMENTS
CONFIGURATION 3I

WTR	80		81		82		83		84		85		86		87		88		89		90	
SHIFT	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
a							4	4														
b							9	9														
c							5	5														
d							11	5														
e							3	1														
f							2	1														
g							17	15														
1ST SHIFT							51															
2ND SHIFT								40														
TOTAL							91															

a. PROPULSION TECH.
b. MECH./STR./THERM. TECH.
c. AVIONICS TECH.
d. ENGINEERING
e. QUALITY CONTROL
f. SAFETY
g. OTHER

TOTAL MANPOWER REQUIREMENTS
CONFIGURATION 3F

	YEAR																					
	80		81		82		83		84		85		86		87		88		89		90	
ETR / SHIFT	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
a									12	8	12	8	12	8	12	8	12	8	12	8	12	8
b									15	10	14	10	14	10	14	10	14	10	14	10	14	10
c									18	12	14	12	14	12	14	12	14	12	14	12	14	12
d									45	30	30	30	30	30	30	30	30	30	30	30	30	30
e									10	6	10	6	10	6	10	6	10	6	10	6	10	6
f									6	4	4	4	4	4	4	4	4	4	4	4	4	4
g									59	38	54	37	54	37	54	37	54	37	54	37	54	37
1ST SHIFT									165		138		138		138		138		138		138	
2ND SHIFT										108		107		107		107		107		107		107
TOTAL									273		245		245		245		245		245		245	

a . PROPULSION TECH.
b . MECH./STR./THERM. TECH.
c . AVIONICS TECH.
d . ENGINEERING
e . QUALITY CONTROL
f . SAFETY
g . OTHER

TOTAL MANPOWER REQUIREMENTS
CONFIGURATION 3F

	YEAR																					
	80		81		82		83		84		85		86		87		88		89		90	
WTR	SHIFT 1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
a									4	4	4	4	5	4	4	4	4	4	5	4	4	4
b									6	6	6	6	10	6	6	6	6	6	10	6	6	6
c									6	6	6	6	8	6	6	6	6	6	8	6	6	6
d									15	0	15	7	15	15	15	7	15	0	15	15	15	0
e									3	0	3	1	5	3	3	1	3	0	5	3	3	0
f									2	0	2	1	3	2	2	1	2	0	3	2	2	0
g									22	16	22	18	29	22	22	18	22	16	29	22	22	16
1ST SHIFT									58		58		75		56		58		75		58	
2ND SHIFT										32		43		58		43		32		58		32
TOTAL									90		101		133		101		90		133		90	

a. PROPULSION TECH.
b. MECH./STR./THERM. TECH.
c. AVIONICS TECH.
d. ENGINEERING
e. QUALITY CONTROL
f. SAFETY
g. OTHER

INNOVATIVE GROUND OPERATIONS TECHNIQUES
(ACTION ITEM 97)

I MDAC APPROACH

Eleven Tug engineering personnel are mandatory during certain Tug prelaunch operations which are time constrained due to Shuttle ground processing schedule requirements. Evaluation of manpower requirements indicates however that during turnaround shifts during which engineering personnel are required, eleven engineers are required only five percent of the time. During the other seventy-five percent of the time, a maximum of nine engineers is only required.

II MDAC POSITION

For those program years requiring four Tug launches per year or less, a field engineering staffing of nine engineers is adequate if, for the five percent of the time when eleven engineers are required, two "home plant" engineers are provided TDY during the five percent peak periods when eleven engineers are required.

III RATIONALE

Program years during which less than four Tug launches per year are listed below:

TUG OPTION	PROGRAM YEAR	LAUNCH SITE
1	1980	ETR
1	1984	WTR
1	1986	WTR
1	1988	WTR
1	1990	WTR
3	1980	ETR

The savings of two engineers during these program years can be equated to $384,000 for Option 1 and $76,800 for Option 3.

IV IMPACTS

Providing home plant engineering personnel to the launch site on a TDY basis for limited periods during program years having launch rates of less than four per year does not impact Tug operations and has precedence on current launch vehicle programs.

Operating in this fusion during program years having launch rates greater than four per year is however neither economical nor efficient.

11.10 Appendix A - Trade Study Results

The operational trade studies are reported in the appropriate section and no "appendix" type material was generated.

APPENDIX B .

MAINTENANCE PLAN

MAINTENANCE

The contractor shall develop a maintenance program that provides optimum Tug System support at the test and launch sites. The maintenance program will have as its objective, a minimum expenditure of support resources over the life of the program. The maintenance concept shall be based on the airline philosophy of on-condition maintenance which minimize performance of maintenance tasks on a specific time interval basis. The contractor will develop the status monitoring and failure prediction techniques necessary to employ this concept. A fault isolation capability to a line replaceable unit (LRU) level will be developed, making maximum use of onboard checkout equipment. Wherever feasible, GSE requirements analyses shall recommend the use of multi-purpose test equipment. A maintenance plan will be prepared defining the types and levels of maintenance, maintenance cycle, maintenance organization and maintenance control functions. A maintenance analysis will be conducted to determine maintenance resource requirements for system, subsystem, LRU and component level. During the maintenance cycle, the primary method of system and subsystem repair will be removal and replacement of LRUs. An optimum repair level analysis will have been completed to determine the most cost effective repair location for each LRU. The interface of the maintenance function with the other elements of integrated logistics support will be defined.

Maintenance Plan

Prepare a maintenance plan that identifies the analysis and planning necessary to provide a program consistent with airline policies and practices. In order to develop the maintenance plan it is necessary to identify maintenance concepts, policies, constraints and requirements. As nearly as possible the maintenance functions of the reusable Tug are related to present airline practices as developed through operating experience and modified to meet Tug needs.

The plan shall specify the approach used for maintenance support of system maintenance, including such elements as implementation of on-condition maintenance, launch site maintenance policies and practices, joint operational and maintenance personnel utilization, vertical and horizontal vehicle maintenance groundrules and distinction between LRU, maintenance significant and nonmaintenance significant hardware categories. Establish the program authority for these plans, and the manner in which they will be maintained current with program development.

Organization - The Maintenance Plan shall describe the maintenance engineering organization that will plan, establish, perform and control maintenance support of the Tug system. The Plan will also define the program authority of the Maintenance organization, and its relationship to other program organizations; e.g., reliability, test, safety and maintainability.

Maintenance Analysis

Define the type and content of maintenance analyses required to establish Level I, II & III maintenance requirements, inspection schedules, maintenance turnaround cycles, GSE, facility interfaces, potential candidates for inflight maintenance, and cost effective procedures. Describe integration and timelines of the maintenance analyses with other Tug program analyses and events. Describe the approach for the utilization of the maintenance data file that enables storage and rapid retrieval of categorized information. The requirement to evaluate field collected maintenance data, and to establish corrective action for apparent problems shall also be considered in the analyses.

The maintenance analyses are performed to identify the system, subsystems and components that require, preventive and/or corrective maintenance. It is based on a systematic analysis of the hardware design to determine the time required to perform each maintenance action and the requirements for specific equipment, facilities, personnel, spares and technical documentation. The analysis is the basic element used in establishing a continuous maintenance program.

Maintenance Analysis Format

The maintenance analysis system will be identified and discussed in detail under this heading of the Plan. The technique for tabulation of the data compiled requiring analysis will also be discussed in this section. Instructions for completion of and format samples of the analysis work sheets will be provided. Format of the work sheets shall be mutually acceptable by both the Government and the Contractor.

Maintenance Support and Control

Describe the test and operational phase of Tug maintenance control that is required to control and administrate maintenance support operations, (e.g., schedule maintenance activities). The Plan shall describe the approach used for the formulation, conduct and authority of the organization, and the optimum physical locations. Define the relationships of the organization with other field organizations, including the operational contractor, giving special attention to the common utilization of personnel for operations and maintenance requirements.

Reports of flight test and operational maintenance actions will be evaluated to determine the degree of effectiveness of maintenance support operations. Describe the approach to be used in the development and implementation of the Tug system data collection program (such as AFSM 310-1, SSD Exhibit 66-1) that encompasses preparation of action reporting forms, field data collection, data evaluation and development of improvement recommendations, whenever applicable. Identify program needs for the collected field data and describe the using agencies plans for maximum program benefits through this effort.

Types of Maintenance

The total system maintenance requirements will be evaluated and segregated in specific types of maintenance, i.e., Postflight, Preventive, Corrective and Calibration. A detailed discussion of the application of these types to the Tug system will be provided in the plan.

Types of Inspection

It is anticipated that several categories of inspection will be required, e.g., Acceptance, Preflight, Postflight, Phased, Special Inspections. Each of these categories will be discussed in the plan to show how each is applied to the maintenance program and what each category of inspection is intended to accomplish.

Levels of Maintenance

- Three levels of effort will be used in support of the continuous maintenance program:

  First - Actions accomplished directly on the vehicle.

  Second - Actions accomplished, in support of first level, off the vehicle in shops or areas located at the Factory/depot.

  Third - Actions accomplished, in support of first and second levels, requiring specialized skills and equipment.

A detailed definition of each level will be provided in the plan, so that it may be used as a reference when making maintenance level assignments for repairable hardware.

Maintenance Philosophy and Concepts

Through evaluation of the analyses, trade-offs and liaison actions, specific maintenance philosophies and concepts will be developed for individual end items, components, assemblies and subassemblies. Such concepts as the following will be included:

- The maintenance program will consist of a structural sampling inspection schedule, a preventative maintenance schedule and corrective maintenance based on the ON-CONDITION concept.
- Corrective system maintenance will be removal and replacement of failed components.
- Application of maintenance status annunciators, maintenance and flight data recorders.

These concepts will be coordinated and integrated with the other affected support activities, e.g., Logistics Engineering, Supply Support, Technical Publications. Training, Operations and Design Engineering. These agreed upon concepts will be recorded in the plan and considered as the baseline program maintenance concept.

Support Equipment and Tools

As a product of the Maintenance Analysis, determine and document the support equipment and tools (CFE, GFE and Commercial) required. Additional sources of supplemental information includes Design Engineering, Operations and the Maintainability Task Analysis. These requirements will be reflected in the plan, segregated to the respective levels of maintenance.

Skill Levels and Manpower

The objective of this exercise is to identify, (1) the job title (skill level) and (2) the requisites (qualifications), formal education, training and experience associated with each skill (grade). This information will be provided in the maintenance plan for correlation with and use in identifying skills during the Maintenance Analysis Program.

In order to facilitate accurate manpower and training plans during the design phase, it is necessary to quantify each skill level required to support the operational system. These requirements are initially identified through the Maintainability Task Analyses and are thoroughly coordinated with the Personnel and Training Group prior to recording them in the Maintenance Plan as firm requirements.

Personnel Utilization Concept

A study will be made to define how maintenance personnel will be cross-trained and utilized in the maintenance, prelaunch and launch activities. The results of this study will be reflected in the Personnel Utilization concepts provided in this maintenance plan.

Maintenance Cycle

The maintenance actions defined and expanded during the maintenance analyses are inputs to be integrated into a total maintenance activity. The maintenance actions will be categorized into one of the types of maintenance discussed; assigned a level of maintenance and diagrammed in a Functional Flow Block Diagram (FFBD), when required. Time spans of each task will be plotted in a timeline study and a specific segment of time designated as the "Maintenance Cycle" time. A detailed discussion of the designated maintenance cycle, through the flight test and operational phases, its timeline and FFBD will be provided.

Periodic Maintenance Control

The automated documentation and scheduling program for periodic (preventive) maintenance requirements of all GSE, (including GFE) support equipment, and stored and installed flight hardware will be defined. Specific direction as to application of this program to the Space Tug Program will be provided in this portion of the plan.

Utilization of Government Owned or Financed Resources

Each requirement involving: facilities, support equipment, tooling or other maintenance resource, will be evaluated in terms of utilizing Government owned or financed resources to satisfy the need. In those areas where Government facilities or resources can be used, appropriate discussions will be provided in the Maintenance Plan. In each instance, maximum use will be made of Government facilities and resources.

Coordination and Interface

The various elements and requirements of the plan are coordinated and completely interfaced with Engineering, Facilities, Operations, Publications, Supply Support, Training, and Operational Contractor to assure the requirements and decisions reflected in the Plan are compatible with, and support their planning and concepts.

Functional Flow Block Diagrams (FFBD)

In order to accurately perceive the magnitude and scope of specific maintenance requirements, it is necessary to diagram the maintenance action in its logical procedural steps. The maintenance plan will provide guidelines to be followed in preparing these FFBD's.

Provisioning Support

This portion of the plan will provide guidelines and parameters of Maintenance Engineering responsibility with respect to support of provisioning activities. Decision making authority will be clearly defined; action to be taken when the provisioning decision is not compatible with the requirements expressed in the maintenance analysis; general outline of the data to be provided and made available during provisioning conferences will be included in this area.

Data Collection

To aid in identifying and eliminating potential problems, correcting existing failures, and improving maintenance capability, a maintenance data collection system will be defined and implemented. The data collection will start with component testing, continue through manufacturing, test and operational phases. Because of the minimum number of vehicles produced and limited flight test program there is a need to gather as much data as early as possible to verify the maintenance and logistics program prior to the operational phase.

The method of collecting field data and the techniques to be applied in the processing and analyses of the data will be described in this section of the plan.

MAINTENANCE FACILITIES

A Maintenance Facility Program Plan will be prepared. This plan will outline the contractors' approach to identifying facility requirements, existing facilities and how the contractor plans to conduct the facility acquisition effort. Personnel engaged in this activity will be responsible for:

- Conduct "on the spot" evaluations of existing maintenance facilities and prepare Site Selection and Evaluation Report for NASA/DOD.

- Identify to NASA/DOD, specific technical requirements and facility design constraints.
- Prepare facility design concepts to facilitate review and analysis of proposed solutions to facility design trade-off. These concepts will include recommended floor and area plans with room or area names, size, functions, elevation plans, clearances and statements of how electrical and mechanical functions are to be carried out.
- Participate in design reviews with NASA/DOD, architects, et al to support the maintenance facility planning aspect of the program.
- Prepare an Activation Plan which consists of consolidating all schedules, plans and associated actions required for total activation of new or modified maintenance facilities.
- Prepare a Master Equipment List of Real Property Installed Equipment (RPIE) and items of electrical and mechanical equipment and their major components, based on the final facility design.
- A Project Status Report will be prepared and updated periodically, to keep NASA/DOD advised of the status of all incomplete maintenance facilities. An Annual Summary Report will be prepared for each active facility contract which will include a summary of all funding actions, inventory transactions and use of facilities under the total contract during the reporting period.

This activity will be concerned with all locations, i.e., launch site and test sites.

MAINTENANCE STATUS REPORTS

Maintenance Status Reports shall be provided to assure proper accounting of all pertinent maintenance elements. The reports will include description of trends, problems and actions taken or deferred. Formal Maintenance Milestone (Schedule) Summary documentation will be initiated as the document for time phasing the Maintenance Program.

Appendix C

SPARES ANALYSIS/PLANNING (UNSCHEDULED MAINTENANCE)

C.1 SPARES QUANTITY AND COST ANALYSIS DATA

The maintainability analyses have addressed unscheduled maintenance requirements. This applies risk of failure analysis methods to prediction of spares requirements. The same basic data were used to predict maintenance manhours, launch reliability and payload changeout risk at the pad (see Section 6.11.7.2). The results of the spares analyses are documented in 3 sets of data contained herein. Cost estimates were introduced into the cost model in terms of initial spares and depot maintenance, measured in terms of equivalent units of production subsystem hardware costs.

The first set of forms entitled preflight verification of subsystems show the failure/anomaly risk analysis basic to the maintenance time and spares cost predictions. The data in the column labeled "$\epsilon = N\lambda KT$" shows risk of failure (failures per flight).

The next series of forms entitled Tug Spares Analysis show subsystem breakdown to Level 8 and spares quantities. The data from the verification of subsystems form (ϵ) are used to calculate the values shown in Columns 2, 3, 8, and 9. Stock level estimates are made as a function of flight frequency, depot flow time and desired probability of sufficient stock for any contingency. The quantity of initial spares (required at Level I to repair any failure present in a returning Tug, SI) is based on a 0.90 probability of sufficient spares to cover 5 flights without resupply. The estimates for Level II maintenance provides at least 1 of each replaceable item if not qualified in SI for Level 1, plus an additional quantity for higher failure risk items to assure a 0.995 probability of sufficient parts over a 5 flight time span. Depot maintenance costs are based on failure rate, estimated number of flights and % of part costs to handle the cost of the repair cycle (30% used for the latter, for refurbishable items). The quantity of initial spares for each component to repair the Tug are shown under "Component Initial Stock". The quantity of operational spares for each item is shown under "Component Float Stock" and "Subassembly Operational Spares". The worksheets showing the calculation of spares costs for the cost model input sheet are shown in the third set of data.

C.2 MATHEMATICAL TECHNIQUES USED IN THE ANALYSES

The customary failure risk prediction technique used in reliability predictions is based on the formula $\Sigma N\lambda KT$ where,

- N = Number of parts in the equipment
- λ = Failure rate of the part
- K = Stress factor for the part for time T (Vibration, heat, etc. effects)
- T = Operating time

For the Risk of Failure prediction shown on the form "Preflight Verification of Subsystems," the following values were used

- N = Number of components or subassemblies (computer, valve, tank, etc.)
- λ = Failure rate of the characteristic item for space
- K = Equivalent anomaly factor*
- T = Flight duration + equivalent space time to compensate for shuttle lift off stresses + prelaunch operations time following tug post maintenance checkout. $\begin{cases}\text{10 Prelaunch Operations;}\\ \text{178 Equivalent Flight Time}\end{cases}$

*The K factor for additional damage was applied to predict work load. Investigations several years ago indicated that operation of equipment in test after transport to a flight location introduced 5 - 8 times the prior number of failures. This same magnitude value was used here to represent the ratio between actual failures (inherent reliability failure rate) and anomalies (degraded performance, suspect items removed as deficient, or items requiring adjustment or calibration prior to dispatch on a new Tug space mission). Thus, the total spares quantity shown includes both the actual flight failures and correction of anomalies.

The cost models used to calculate spares costs in terms of equivalent assembly (Level 6) and subsystem (Level 5) costs are:

For Initial Spares as a function of assembly cost:

$$EI_K = \sum_{j=1}^{N_j} SO_j . R_j . C_j + C1_j \sum_{i=1}^{N_i} SI_i$$

and

For Operating Spares as a function of assembly cost:

$$EO_K = \sum_{j=1}^{N_j} SO_j . R_j . C_j + C1_j \sum_{i=1}^{N_i} SO_i$$

and

For Depot Spares as a function of assembly cost:

$$ED_K = \sum_{j=1}^{N_j} SD_j . R_j . C_j + C1_j \sum_{i=1}^{N_i} SD_i$$

For Initial Spares as a function of subsystem cost:

$$EI_L = \sum_{k=1}^{N_k} EI_K . C2_K$$

Operating or Depot Spares as a function of subsystem costs (EO_L or ED_L) are found by substituting EO_K or ED_K in the last equation.

The meanings of the symbols used follow:

SI_j = Number of initial spares of component j.

SI_i = Number of initial spares of subassembly i.

SO_j = Number of operating spares of component j.

SO_i = Number of operating spares of subassembly i

SD_j = Number of depot repair kits and/or parts as equivalent components

SD_i = Number of depot repair kits and/or parts as equivalent subassemblies

C_j = Cost of component j in equivalent assemblies

$C1_j$ = Average cost of subassembly i in equivalent components = $\frac{C_j}{N_i}$

$C2_k$ = Cost of assembly k in equivalent subsystems L

R_j = The ratio of the cost of a spare component j to the cost of a shipset of component j.

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL 1 & 3I

Code No.	Functional Equipment Items	Funct Prior to Flt	Verification Capability						No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	$N\lambda KT$	Attrib. Items R
			Parameter	% Risk	Method	Locat.	Test	No. Test						
1.	Structure			100									.251	
1.1	Fuel Tank													
1.1.1	Access Cover Gaskets		Leakage	67	Hold Pressure	1.2.1	X		2		5		.02	
	Tank Repair Kit		Struct Damage	33	Visual	1.1.7		X					.01	
1.2	LOX Tank													
1.2.1	Access Cover Gaskets		Leakage	67	Hold Pressure	1.2.1	X		2		5		.02	
	Tank Repair Kit		Struct. Damage	33	Visual	1.1.7		X					.01	
1.3	Body Struct													
1.3.1	Paint		Appearance	60	Visual	1.1.7		X			5		.03	
1.3.2	Access Cover Panels		Tears/cracks	40	Visual	1.1.7		X	4		5		.02	
1.4	Thrust Struct.													
1.4.1	Supports		Distortion	100	Visual	1.1.7		X			5		.01	
1.5	Meteoroid Shield													
1.5.1	Repair Kit - Al		Punctures	50	Visual	1.1.6		X			100		.05	
1.5.2	Repair Kit - Fbglas.		Punctures	50	Visual	1.1.6		X			100		.05	

PREFLIGHT VERIFICATION OF SUBSYSTEMS
MODEL 1 & 3I

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability: Parameter	% Risk	Method	Locat	Test	No. Test	No. N	Fail/10^6 Hr λ	Stress Factor K	Use Time T	NAKT	Attrib. Items R
1.6	Payload Docking			100									.0310	
1.6.1	Latches		No Binding		Actuate	2.2.3	X		4				.0040	
1.6.2	Latch Trigger		Lock, Binding		Actuate	2.2.3	X		4				.0040	
1.6.3	Retract Cylinder		Release, Actuate		Actuate	2.2.3	X		4				.0072	
1.6.4	Valves & Plumbing		Actuate Ret. Cyl.		Actuate	2.2.3	X		-				.0020	
1.6.5	Docking Ring Assy		Struct. Sound		Visual	2.2.3	X		1				.0002	
2.0	Thermal Control			100									.0610	
2.1	Tank Paint		Condit., Coverage	49	Visual	1.1.6	X		1				.0300	
2.2	Insulation Purge												.0310	
2.2.1	Liner Repair Kit		Hold Press.	49	Press. Test	1.1.7	X		1				.0300	
2.2.2	Plumbing		Hold Press.	1	Flow Test	1.1.7	X		-			70	.0005	
2.2.3	Valves		Actuate Purge	1	Flow Test	1.1.7	X		4	1.0	8	70	.000560	

2-6

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: 1 & 3I

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability: Parameter	% Risk	Method	Locat	Test	No. Test	No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
3.0	Avionics													
3.1	Data Management	2A		Est 84									.194740	
3.1.1	Computer (Class B)			23.3	Computer				1	100	7	15 50	.045500	
	Central Process.		Collect & Proc. Data		Subroutines	2.4.1	X		(1)	(20)	7	15 50	(.0009100)	
	Memory Stack		Integrate Data		Subroutines	2.4.1	Part.		(3)	(25)	7	15 50	(.034125)	
	Box - Misc.		Computer Function		Subroutines	2.4.1	X		(1)	(5)	7	15 50	(.002275)	
3.1.2	Mod. Interface Unit.			67.3	Computer								.131040	
	Bus Interface Unit		Back up Bus		Subroutines	2.4.1	Part.		10	4	7	15 50	(.018200)	
	Power Control U		Power Control		Subroutines	2.4.1	Part.		24	4	7	15 50	(.043680)	
	Discrete Commd U		Transfer Commands		Subroutines	2.4.1	Part.		16	4	7	15 50	(.029120)	
	Remote Multplx U		Multiplex Data		Subroutines	2.4.1	Part.		16	4	7	15 50	(.029120)	
	Data Interface U		Transfer Data		Subroutines	2.4.1	Part.		2	4	7	15 50	(.003640)	
	Signal Condit. U		Proper Measurement		Subroutines	2.4.1	Part.		4	4	7	15 50	(.007280)	
3.1.3	DCU			9.4	Subroutines	2.4.1	Part.		1/2	40	7	15 50	.018200	

Stress Factor = 1 + K_{GROUND} = FLT FAIL + ANOMOLIES INTRODUCING MAINT.: T = GROUND OPS + FLT OPS + T EQUIV. FOR LAUNCH

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL 1 & 3I

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability: Parameter	% Risk	Method	Locat	Test	No. Test	No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
3.2	GNC	3C		70.1									.076320	
3.2.1	IMU	x							2/	85	8	2 40	.057120	
3.2.1.1	Gyro Assy		Stabilize		Meas. Speed	2.4.4	X		(6)	(7.4)	8	2 40	(.014918)	
3.2.1.2	Accellerometers		Displacement		Bench Test	1.1.13		X	(6)	(3.4)	8	2 40	(.006854)	
3.2.1.3	Sensor Electronics		Input-Output Data		Operating Data	2.4.4	X		(2)	(16.4)	8	2 40	(.011021)	
3.2.1.4	Power Supply ϕ Elect.		Power to Units		Unit Funct.	2.4.4	X		(2)	(20)	8	2 40	(.013440)	
3.2.1.5	Housing & Coolant - Misc.		Temp. Cont.		Measure - TM	2.4.4	X		(2)	(16.2)	8	2 40	(.010886)	
3.2.2	Start Sensor								2^D	30	8	40	.019200	
3.2.2.1	Sensor		Sense/Track Stars		Light Table	1.1.13		X	(2)	(25)			(.016000)	
3.2.2.2	Stabilization/ Drive		Control Sensor Posit.		Test Response	1.2.1	X		(2)	(5)			(.003200)	
3.3	Communications	(A)		99.2									.066040	
3.3.1	Antenna	x	Data Output	100	Test For TM	2.4.1	X		4	3.6	5	15 40	.003960	
3.3.2	Multiplexer	x	Sequence Data	100	Test for TM	2.4.1	X		1	4	8	15 40	.001760	

C-8

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: 1 & 3I

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability: Parameter	% Risk	Method	Locat	Test	No. Test	No. N	Fail/10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
3.3.3	Power Amplifier			100			X		1	49	8	15 40	.021560	
	TWT		Voltage		Monitor by TM	2.4.1	X		(4)	(11)	8	15 40	(.019360)	
	Circuitry		Power Avail		TM Communic.	2.4.1	X		(1)	(5)	8	15 40	(.002200)	
3.3.4	Transponder	x	Relay Data	100	Interrog.	1.1.13		X	1/2	10	8	5 40	.004400	
3.3.4.1	PC Board								(4)	8			(.003520)	
3.3.5	Commd. Decoder	x	Equip. Function	100	TM Command	2.4.1	X		1/2	4	8	15 40	.001760	
3.3.6	Processor	x		85			Part.		1	8	8	15 40	.003520	
3.3.6.1	PC Boards		Data Input to TM		Interrog. TM	2.4.1	Part.		2	3	8	15 40	(.002640)	
3.3.6.2	Circuitry		Data Input to TM				Part.		1	2	8	15 40	(.000880)	
3.3.7	Commd. Encoder	x	Equip. Funct.	100	TM Command	2.4.1	X		1	17[M]	8	15 40	.007480	
3.3.8	Tape Recorders	x		100				x	2	30	8	5 40	.021600	
3.3.8.1	Tape Drive Mech		Position Tape		Oper. T.R.	2.4.1			2	6	8	5 40	(.004360)	
3.3.8.2	Magnetic Heads		Read/Energize Tape		Oper. T.R.	2.4.1			2	2	8	5 40	(.001440)	
3.3.8.3	Electronics		Control		Oper. T.R.	2.4.1			2	22	8	5 40	(.015840)	

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: 1 & 3I

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability: Parameter	% Risk	Method	Locat	Test	No. Test	No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
3.4	Instrumentation	(Limited)		94.6									.026424	
3.4.1	Sensors	x		99.1							8		.018024	
3.4.1.1	Strain		Continuity		Test Software	1.2.1		X	10	$.05^{O}$	8	1 40	(.000164)	
3.4.1.2	Press. Transducers		Press Actuation		Loading Opns.	2.4.2	X		25	$.1^{M}$	8	2 40	(.000840)	
3.4.1.3	Temp. Transducers		Temp Actuation		Loading Opns.	2.4.2	X		30	3^{M}	8	15 40	(.004220)	
3.4.1.4	Position Sensors		Position Indic.		Checkout	1.2.1	Part.		20	2^{D}	8	40	(.012800)	
3.4	Signal Conditioning	x		85			X		1	25	8	2 40	(.008400)	
3.4.2.1	Misc. Conditioning		Proper Signal Char.		Test Software	2.4.2			85	.3	8			
3.5	Elect. Power Source			100									.050720	
3.5.1	Batteries - Sil. 2 Inc.		Power Avail.	100	On Prior to L.O.	2.4.4	X		1	20	8	2	.000320	
			Replace after each flt.									+	1.0	
3.5.2	Battery - TVC		Power Avail	100	On Prior to L.O.	2.4.4	X		1	20	8	0	0	
			Replace after each flt.									+	1.0	

C-10

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: 1 & 3I

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability						No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	MAKT	Attrib. Items R
			Parameter	% Risk	Method	Locat	Test	No. Test						
3.6	Power Distrib.													
3.6.1	Power Dist. Units			100					1	150	8	2 40	.050400	
3.6.1.1	Motor Driv. Switches		Power Available	5.4	Use in C/O	2.4.1	X		4	2			(.002688)	
3.6.1.2	Relays		Power Available	28.0	Use in C/O	2.4.1	X		14	13			(.014112)	
3.6.1.3	Busses & Circuitry		Power Available	66.6	Use in C/O	2.4.1	X		1	100			(.033600)	
4.0	Propulsion													
4.1	Main Engine			0										
4.1.1	Main Engine			0						14000	8	.50	.056000	(.034237)
4.1.1.1	Igniter		Energy Avail.		Excite	1.1.7		X	1	20.0	5	.50	(.000050)	
4.1.1.2	Ignition Exciter		Energy Avail.		Apply Power	1.1.7		X	1	5.0	8	.50	(.000020)	
4.1.1.3	Prestart Solenoid Vlv.		Open/Close		Act.-Posit. Sens.	1.1.7		X	1	11.0	8	57	(.005016)	
4.1.1.4	Prestart Hc Press Sw.		Open/Close		Act.Posit. Sens.	-		X	1	1.5	8	57	(.000684)	
4.1.1.5	Start Solenoid Vlv.		Open/Close		Act. Posit. Sens.	1.1.7		X	1	11.0	8	57	(.005016)	
4.1.1.6	Start Hc Press. Sw.		Open/Close		Act.-Posit. Sens.	-		X	1	1.5	8	57	(.000684)	
4.1.1.7	Igniter Oxid. Supply Vlv.		Open/Close		Act.-Posit. Sens.	1.1.7		X	1	.6	8	57	(.000274)	

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL 1 & 3I

Code No.	Functional Equipment Items	Funct Prior To Flt.	Verification Capability: Parameter	% Risk	Method	Locat	Test	No. Test	No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	$N\lambda KT$	Attrib. Items R
4.1.1.12	Main Fuel S/O Vlv.		Open/Close		Act.-Posit. Sens.	1.1.7		X	1	11.0	8	.50	(.000044)	
-	Oxid. Flow Cont. Vlv		Not feasible to replace without engine overhaul							-			-	
-	Thrust Cont. Valve									-			-	
-	Oxidizer Pump									-			-	
-	Fuel Pump									-			-	
4.1.1.8	Fuel Pump Disch Cool Down Vlv		Open/Close		Act. Posit. Sens	1.1.7		X	1	.5	5	.5	(.000013)	
4.1.1.9	Fuel Pump Interstage Cool Dn Vlv		Open/Close		Act. Posit. Sens.	1.1.7		X	1	.5	5	.5	(.000013)	
4.1.1.10	Oxid. Inlet S/O Valve		Open/Close		Act. Posit. Sens.	1.1.7		X	1	.6	5	.5	(.000015)	
4.1.1.11	Fuel Inlet S/O Valve		Open/Close		Act. Posit. Sens.	1.1.7		X	1	.6	5	.5	(.000015)	
4.1.1.15	Sensors/ Transducers					-		X	8				(.011172)	
4.1.1.15.1	Press		Read Press		Flt. only	-		X	4	6.0	8	57	(.009804)	
4.1.1.15.2	Temp		Read Temp		Flt. only	-		X	3	1.0	8	57	(.001368)	
4.1.1.15.3	Speed Transducer		Read R/M		Eng. Oper only	-		X	1	5	5	.5	(.000012)	
4.1.1.13	Gimbal Assy		Crack		Visual	1.1.7		X	1	1	3	.5	(.000002)	
4.1.1.14	Interstage Bleed & P/R Vlv.		Open/Close		Act. Posit. Sens.	1.1.7		X	1	11	5	.5	(.000028)	

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: 1 & 3I

Code No.	Functional Equipment Items	Funct Prior To Flt.	Verification Capability: Parameters	% Risk	Method	Locat	Test	No. Test	No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NAKT	Attrib. Items R
4.1.1.16	Fuel Tank Press Valve		Open/Close		Act. Posit. Sens.	1.1.7		X	1	3	5	.5	(.000007)	
4.1.2	Gimbal Actuators (TVC)			0					2		8	1.0 .5	.000924	
4.1.2.1	Motor Actuators		Actuate Screw		Operate/Visual	1.1.7		X	(4)	10.89	8	1.0 .5	(.000522)	
4.1.2.2	Magnetic Clutch		Actuate Screw		Operate/Visual	1.1.7		X	(4)	2.4	8	1.0 .5	(.000114)	
4.1.2.3	Velocity Xducer		Measure Vel.		TM Feedback	1.1.7		X	(4)	.3	8	1.0 .5	(.000012)	
4.1.2.4	Position Xducer		Measure Posit.		TM Feedback	1.1.7		X	(4)	.13	8	1.0 .5	(.000006)	
4.1.2.5	Servo Amplifier		Feedback Sign.		Operate	1.1.7		X	(4)	5.6	8	1.0 .5	(.000270)	
4.1.2.6	Ball Screw		Travel		Operate-Travel	1.1.7		X	(2)	.001	8	1.0 .5	-	
4.1.2.7	Bellows		Seal Unit.		Visual	1.1.7		X	(2)	.001	8	1.0 .5	-	
4.1.2.8	Case Valve		Relief Setting		Test Pressure	1.1.7		X	(2)	.001	8	1.0 .5	-	
4.2	Propulsion Support												.052359	
4.2.1	Propellant Feed			69.3	Verifiable					89.6	5		.004618	
4.2.1.1	LH_2 Feedline Ball Valve	No	Seal Fuel	23.1	Tank Leak Test	1.1.7	X		1	3.0	5	2 69	(.001065)	
4.2.1.2	LO_2 Feedline Ball Valve	No	Seal Oxidizer	23.1	Tank Leak Test	1.1.7	X		1	3.0	5	2 69	(.001065)	

PREFLIGHT VERIFICATION OR SUBSYSTEMS

MODEL 1 & 3I

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability: Parameter	% Risk	Method	Locat	Test	No. Test	No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
4.2.1.3	1/2 in. Check Valve	Yes	Check Flow	15.4	Isol. C/V Test	1.1.7		X	1	2.0	5	2 69	(.000710)	
4.2.1.4	LH_2 Feedline Isol. Monitor	Yes	Sense Valve Pos.	11.5	Valve Posit. SEns.	1.1.7	X		1	1.5	5	2 69	(.000533)	
4.2.1.5	Ball Valve Pneu. Actuator	No	Open/Close	-	Act. Valve	1.1.7		X	1	4	5	.5 69	(.000001)	
4.2.1.6														
4.2.1.7	LO_2 Feedline Isol. Monitor	Yes	Sense Valve Pos.	11.5	Valve Posit. Sens.	1.1.7	X		1	1.5	5	2 69	(.000533)	
4.2.1.8	1/2 in. Check Valve	Yes	Check Flow	15.4	Isol. C/V Test	1.1.7		X	1	2.0	5	2 69	(.000710)	
4.2.1.9	Ball Valve Pneu. Actuat.	No	Open/Close	-	Act. Valve	1.1.7		X	1	.4	5	.5	(.000001)	
4.2.2	Vent (#1)			56.6					1		5	2 69	.014314	
4.2.2.1	Isolation Valves - LH_2	No	Leak to Vent	16.9	Test for Leaks	1.1.7		X	2/4	3.4	5	2 69	(.002414)	
4.2.2.2	Tug/Orbiter Ftg LH_2	Yes	Leak at Face	4.8	Halogen Test	2.3.9	X		1	1.96	5	2 69	(.000696)	
4.2.2.3	Vent & Relief Valves - LH_2	Yes	Open to Vent	28.3	Relief Setg.	1.1.7	X		2	5.7	5	2 69	(.004047)	
4.2.2.4	Isolation Valves LO_2	No	Leak to Vent	16.9	Test for Leaks	1.1.7		X	2/4	3.4	5	2 69	(.002414)	
4.2.2.5	Tug/Orbiter Ftg LO_2	Yes	Leak at Face	4.8	Halogen Test	23.3.9	X		1	1.96	5	2 69	(.000696)	
4.2.2.6	Vent & Relief Valves LO_2	Yes	Open to Vent	28.3	Relief Setg	1.1.7	X		2	5.7	5	2 69	(.004047)	

A-14

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL 1 & 3I

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability: Parameter	% Risk	Method	Locat	Test	No. Test	No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
4.2.3	Fill & Drain			100					1				.007335	
4.2.3.1	F&D Valve - LH_2	Yes	Open/Close	34.5	Fill Cycle	2.4.3	X		3	3.4	5	2 69	(.003621)	
4.2.3.2	F&D Valve - LO_2	Yes	Open/Close	34.5	Fill Cycle	2.4.3	X		3	3.4	5	2 69	(.003621)	
4.2.3.3	Disconnect LH_2	Yes	Seal to Orb.	10.3	Halogen Test	2.3.9	X		1	1.96	8	2	(.000031)	
4.2.3.4	Disconnect LO_2	Yes	Seal to Orb.	20.7	Halogen Test	2.3.9	X		2	1.96	8	2	(.000062)	
4.2.4	Pneumatic			100					1				.017380	
4.2.4.1	S/O Valve Modules	Part.	Open/Close	100	Actuate Valves	1.1.7			22	2.0	5	10 69	(.017380)	
4.2.5	Propellant Utilization			100					1				.004594	
4.2.5.1	LH_2 Capac. Probe	Yes	Quantity Meas.	50	Monitor Fill	2.4.3	X		1	1.0	8	2 69	(.000568)	
4.2.5.2	LO_2 Capac. Probe	Yes	Quantity Meas.	50	Monitor Fill	2.4.3	X		1	1.0	8	2 69	(.000568)	
4.2.5.3	Prop. Utiliz Assy	No	Control Flow	0	Calib.	1.1.7		X	1	6.2	8	69	(.003422)	
4.2.5.4	Capac. Probe Attach.	Yes	Seal Tank	-	Hold Press.	1.1.7	X		2	.05	5	2 69	(.000036)	
4.2.6	Pressurization			99.9					1				.004118	
4.2.6.1	Tanks He	Yes	Leakage	2.4	Press Decay	2.4.2	X		5	0.05	5	10 69	(.000099)	
4.2.6.2	Regulator	Yes	Regulated Press.	48.0	Press. Txdcr	2.4.2	X		2	2.5	5	10 69	(.001975)	

A-15

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: 1 & 3I

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability						No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	$N\lambda KT$	Attrib. Items R
			Parameter	% Risk	Method	Locat	Test	No. Test						
4.2.6.3	Shut Off Valves (Sol)	Yes	Leakage	19.2	Press. Decay	2.4.2	X		2	1.0	5	10 69	(.000790)	
4.2.6.4	Plenum	Yes	Leakage	0.4	He Loss	2.4.2	X		1	0.05	5	2 69	(.000018)	
4.2.6.5	Relief (Burst)	Yes	Leakage	1.0	Press. Decay	2.4.2	X		1	0.10	5	10 69	(.000040)	
4.2.6.6	Fill Adapter	Yes	Leak-Interface	0.5	Halogen Test	2.3.9	X		1	0.05	5	10 69	(.000020)	
4.2.6.7	LH_2 Tank Press. Valve	Yes	Open/Close	8.6	Press. Avail.	1.1.7	X		1	1.0	5	2 69	(.000355)	
4.2.6.8	LH_2 Tank Press. Orifice	Yes	Flow Rate	0.9	Press. Avail.	2.4.3	X		1	0.10	5	2 69	(.000036)	
4.2.6.9	Eng. Press. Orifice (GH)	No	Flow Rate	-	Calib.	MF6		X	1	0.10	5	.5	(.000001)	
4.2.6.10	Eng. Press. S/O Valve	No	Open/Close	0.1	Monitor Posit.	1.1.7		X	1	1.0	5	.5	(.000003)	
4.2.6.11	LO_2 Tank Press. Valve	Yes	Open/Close	17.2	Press. Avail.	2.4.3	X		2	1.0	5	2 69	(.000710)	
4.2.6.12	LO_2 Tank Press. Orifice	Yes	Flow Rate	1.7	Press. Avail.	2.4.3	X		2	0.10	5	2 69	(.000071)	
4.3	ACPS Engine			0									.007097	
4.3.1	ACPS Module								4				.002534	
4.3.1.1	R-30 Engine	No	Flow Rate		Calib.	1.1.12		X	(16)	.32	10	12	(.000614)	
4.3.1.2	Thrustor Isolation Va	No	Open/Close		Monitor	1.1.12		X	(16)	1.0	5	12	(.000960)	
4.3.1.3	Thrustor Cont. Va.	No	Open/Close		Monitor	1.1.12		X	(16)	1.0	5	12	(.000960)	

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: 1 & 3 I

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability: Parameter	% Risk	Method	Locat	Test	No. Test	No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NAKT	Attrib. Items R
4.4	ACPS Eng. Support			100									.004563	
4.4.1	Tank	Yes	Leakage		Tank Press.	2.1.7	X		3	1.0	5	10 69	.001185	
4.4.1.1	Tank Bladder	Yes	GN_2 Barrier		Tank Press.	2.4.2	X		(3)	0.9	5	10 69	(.001051)	
4.4.2	Relief Valve	Yes	Rel. Setting		Tank Press.	2.4.2	X		(10	0.10	5	10 69	.000040	
4.4.3	Fill Valve GN_2	Yes	Open/Close		GN_2 Press.	2.4.2	X		(10	1.0		10 69	.000395	
4.4.4	Fill Fitting GN_2	Yes	Leak	-	Monitor Fill	2.4.2	X		(1)	0.05	5	1	.000001	
4.4.5	Fill Valve N_2H_4	Yes	Open/Close		Monitor Fill	2.1.7	X		(1)	1.0	5	10 69	.000395	
4.4.6	Fill Fitting - N_2H_4	Yes	Leak	-	Monitor Fill	2.1.7	X		(1)	0.05	5	1	.000001	
4.4.7	Screen Filter	No	Flow Rate		Flight Data	1.1.7		X	(1)	0.10	5	12	.000006	
4.4.8	Module Isol. Valve	Yes	Leakage		Monitor Press.	2.4.2	X		(4)	1.0	5	10 69	.001580	
4.4.9	Module Instal. Connect	No	Proper Mod. Cmmds		Software	2.1.7	X		4	2.5	8	12	.000960	

Code	Functional Equipment (Assembly, Component, Subassy)	Number Per Tug	Level I Maintenance						Level II Maintenance						Repair Subassy at Depot
Code 1.1.1.1 — Subassembly Level 8; Component Level 7; Assembly Level 6			Failures Per 100 Flts	Failures Per 5 Flts	Replace Comp/LRU	Repair Tug	Component Initial Stock	Component Float Stock (OFS)	Subassy Failed/ 100 Flts	Subassy Failed/ 5 Flts	Replace Subassy	Repair Component	Subassy OPS Spares	Subassy Repair Kits-Depot	
1.	Structure														
1.	Structure														
1.1	Fuel Tank	1													
1.1.1	Access Gaskets	(5)	2	0.1	X		0						2	0.005	TA
1.1.2	Structure Repair Kit	(1)				X	0		1	0.05			1	0.005	
1.2	Oxidizer Tank	1													
1.2.1	Access Gaskets	(5)	2	0.1	X		0						2	(0.005)	TA
1.2.2	Structure Repair Kit	(1)				X			1	0.05		X	1	(0.005)	
1.3	Body Structure	1													
1.3.1	Paint	(1)	3	0.15		X	1					X	1	(0.05)	
1.3.2	Access Panels and Orbiter Interface Kit	(1)				X	0		2	0.10		X	1	(0.02)	
1.4	Thrust Structure	1													
1.4.1	Repair Kit	(1)				X	0		1	0.05		X	1	(0.03)	
1.5	Meteoroid Shield	1													
1.5.1	Repair Kit Aluminum Sandwich	(1)				X	0		5	0.25		X	1	(0.02)	
1.5.2	Repair Kit FBCLS	(1)				X	0		5	0.25		X	1	(0.02)	
1.6	Payload Docking	1	3.1	0.17											
1.6.1	Latches	4	0.5	0.03	X		0						1	0.2	X
1.6.2	Latch Trigger	4	0.5	0.03	X		0						1	0.2	X
1.6.3	Retract Cylinder	4	1.0	0.05	X		0						1	0.5	X
1.6.4	Plumbing (Kit)	1	1.0	0.05		X	0					x	1	0.2	TA
1.6.5	Frame Tube	1	0.1	0.01	X		0						1	0.2	X

Code - 1.1.1.1 ← Subassembly Level 8
Component Level 7
Assembly Level 6

Code 2.	Functional Equipment (Assembly, Component, Subassy) Thermal Control	Number Per Tug	Level I Maintenance: Failures Per 100 Flts	Level I Maintenance: Failures Per 5 Flts	Level I Maintenance: Replace Comp/LRU	Level I Maintenance: Repair Tug	Level I Maintenance: Component Initial Stock	Level I Maintenance: Component Float Stock (OPS)	Level II Maintenance: Subassy Failed/100 Flts	Level II Maintenance: Subassy Failed/5 Flts	Level II Maintenance: Replace Subassy	Level II Maintenance: Repair Component	Level II Maintenance: Subassy OPS Spares	Level II Maintenance: Subassy Repair Kits-Depot	Repair Subassy at Depot
2.0	Thermal Control														
2.1	Tank Paint	1	3	0.15		X						X	1	0.25	TA
2.2	Insulation Purge														
2.2.1	Liner Repair Kit	1	3	0.15		X						X	1	0.01	
2.2.2	Plumbing	1	0.05	0.002	X							X	1	0.001	TA
2.2.3	Valves	2	0.06	0.002	X							X	1	0.001	X

Code - 1.1.1.1 — Subassembly Level 8
Component Level 7
Assembly Level 6

Code	Functional Equipment (Assembly, Component, Subassy)	Number Per Tug	Level I Maintenance: Failures Per 100 Flts	Failures Per 5 Flts	Replace Comp/LRU	Repair Tug	Component Initial Stock	Component Float Stock (OPS)	Level II Maintenance: Subassy Failed/ 100 Flts	Subassy Failed/ 5 Flts	Replace Subassy	Repair Component	Subassy OPS Spares	Subassy Repair Kits-Depot	Repair Subassy at Depot
3.	Avionics														
3.0	Avionics														
3.1	Data Management	-	-	-											
3.1.1	Computer	1	4.55	0.23	X		1	1			X				
3.1.1.1	Central Processor	(1)							0.91	0.05	X		1	1.2	X
3.1.1.2	Memory Stack	(3)							3.42	0.17	X		2	4.5	X
3.1.1.3	Unit Misc (Box)	(1)							0.23	0.01				0.3	X
3.1.2	Module Interface Unit	REF												-	
3.1.2.1	Bus Interface Unit (BIU)	10	1.82	0.09	X		0						1	1	X
3.1.2.2	Power Control Unit (PCU)	24	4.37	0.22	X		1						2	6	X
3.1.2.3	Discrete Command Unit (DCU)	16	2.91	0.15	X		1						2	4	X
3.1.2.4	Remote Multiplex Unit (RMU)	16	2.91	0.15	X		1						2	4	X
3.1.2.5	Data Interface Unit (DIU)	2	0.36	0.02	X		0						1	0.6	X
3.1.2.6	Signal Conditioning Unit (SCU)	4	0.73	0.04	X		0						1	1.0	X
3.1.3	DCU	2	1.82	0.09	X		0						1	2.5	X
3.1.4	System Control Unit														
3.1.4.1	PC Board A														
3.1.4.2	PC Board B	Cancelled with 1 Computer 8-15-73 in #2													
3.1.4.3	Unit Misc (Box)														
3.2	Guidance Navigation, and Control	-	-	-											
3.2.1	IMU	6	5.71	0.29	X		1				X				
3.2.1.1	Gyro Assembly	(6)							1.49	0.07	X		1	2	X
3.2.1.2	Accelerometers	(6)							0.07	0.03	X		1	0.2	X
3.2.1.3	Sensor Electronics	(2)							1.10	0.06	X		1	1.5	X
3.2.1.4	Power Supply and Electronics	(2)							1.34	0.07	X		1	2	X
3.2.1.5	Housing and Coolant	(2)							1.09	0.05				1.4	X

C-20

Code - 1.1.1.1 (Assembly Level 6 / Component Level 7 / Subassembly Level 8)	Functional Equipment (Assembly, Component, Subassembly)	Number Per Tug	Level I Maintenance: Failures Per 100 Flts	Level I Maintenance: Failures Per 5 Flts	Level I Maintenance: Replace Comp/LRU	Level I Maintenance: Repair Tug	Level I Maintenance: Component Initial Stock	Level I Maintenance: Component Float Stock (OPS)	Level II Maintenance: Subassy Failed/100 Flts	Level II Maintenance: Subassy Failed/5 Flts	Level II Maintenance: Replace Subassy	Level II Maintenance: Repair Component	Level II Maintenance: Subassy OPS Spares	Level II Maintenance: Subassy Repair Kits-Depot	Repair Subassy at Depot
3	Avionics (Cont)														
3.2.2	Star Sensor	2	1.92	0.10	X		0				X		1		
3.2.2.1	Sensor	(2)							1.60	0.08	X		1	2.0	X
3.2.2.2	Stabil Drive	(2)							0.32	0.02	X		1	0.4	X
3.3	Communications														
3.3.1	Antenna	4	0.22	0.01	X		0		0.22	0.01			1	0.3	X
3.3.2	Multiplexer	1	0.18	0.01	X		0		0.18	0.01			1	0.3	X
3.3.3	Power Amplifier	1	2.15	0.11	X		1				X		1		
3.3.3.1	TWT	(4)							1.94	0.10			2	9.0	TA
3.3.3.2	Circuitry	(1)							0.22	0.01			1	0.3	X
3.3.4	Transponder	2	0.44	0.02	X		0						1		
3.3.4.1	PC Board	(4)							0.35	0.02			1	0.4	
3.3.4.2	Component Circuits	(2)							0.09	-			0	0.10	X
3.3.5	Command Decoder	2	0.17	0.01	X		0						1	0.3	X
3.3.6	Processor	1	0.35	0.02	X		0				X		1		
3.3.6.1	PC Boards	(2)							0.26	0.01	X		1	0.4	X
3.3.6.2	Circuitry	(1)							0.09	-				0.2	X
3.3.7	Command Encoder	1	0.75	0.04	X		0						1	1.0	X
3.3.8	Tape Recorders	2	2.16	0.11	X		1							0.50	
3.3.8.1	Tape Drive Mechanics	(2)							0.44	0.02	X		1	0.6	X
3.3.8.2	Magnetic Heads	(2)							0.14	0.01	X		1	1.0	TA
3.3.8.3	Electronics	(2)							1.58	0.07				2.0	X

Code - 1.1.1.1 ← Subassembly Level 8
Component Level 7
Assembly Level 6

Code	Functional Equipment (Assembly, Component, Subassy)	Number Per Tug	Level I Maintenance: Failures Per 100 Flts	Failures Per 5 Flts	Replace Comp/LRU	Repair Tug	Component Initial Stock	Component Float Stock (OPS)	Level II Maintenance: Subassy Failed/ 100 Flts	Subassy Failed/ 5 Flts	Replace Subassy	Repair Component	Subassy OPS Spares	Subassy Repair Kits-Depot	Repair Subassy at Depot
3.	Avionics (Cont)														
3.4	Instrumentation														
3.4.1	Sensors	1	1.80												
3.4.1.1	Strain	(10)	0.02	0.001		X	0						3	0.1	TA
3.4.1.2	Press Transducers	(25)	0.08	0.004	X		0						10	0.1	TA
3.4.1.3	Temp Transducers	(30)	0.42	0.021	X		0						10	0.2	TA
3.4.1.4	Position Sensors	(20)	1.28	0.064	X		0						10	0.3	TA
3.4.2	Signal Conditioning	1													
3.4.2.1	Signal Conditioning Units	(65)	0.84	0.04			0						20	0.1	TA
3.4.3	Circuitry														
3.5	Electrical Power Source	1	0.03												
3.5.1	Batteries - Silicon Zinc	2	0.03	0.002			0						0.4	-	TA
			Replace After Flt - Above are Random Fail. Only.												
3.5.2	Battery - TUC	1	0				0						1	-	TA
			Replace After Flt - Covered in Scheduled Maint. Quantities.												
3.6	Power Distribution	1													
3.6.1	Motor Driven Switches	(4)	0.27	0.01	X		0						1	0.5(.20)	X
3.6.2	Relays	(14)	1.41	0.07	X		0						3	6.5(.20)	TA
3.6.3	Busses and Circuitry (Kit)	(1)	3.36	0.17		X						X		1.8(.02)	X

Code 4.	1.1.1.1 — Subassembly Level 8; Component Level 7; Assembly Level 6. Functional Equipment (Assembly, Component, Subassy) Propulsion	Number Per Tug	Level I Maintenance: Failures Per 100 Flts	Level I Maintenance: Failures Per 5 Flts	Level I Maintenance: Replace Comp/LRU	Level I Maintenance: Repair Tug	Level I Maintenance: Component Initial Stock	Level I Maintenance: Component Float Stock (OPS)	Level II Maintenance: Subassy Failed/100 Flts	Level II Maintenance: Subassy Failed/5 Flts	Level II Maintenance: Replace Subassy	Level II Maintenance: Repair Component	Level II Maintenance: Subassy OPS Spares	Level II Maintenance: Subassy Repair Kits-Depot	Repair Subassy at Depot
4.1.1	Engine	(1)	5.60	0.28	X		1								X
4.1.1.1	Igniter	1	0.005	-	X		0				X		1	0.1	X
4.1.1.2	Ignition Exciter	1	0.002	-	X		0				X		1	0.1	X
4.1.1.3	Prestart Solenoid Valve	1	0.502	0.025	X		0				X		1	0.8	X
4.1.1.4	Prestart He Pressure Switch	1	0.070	0.003	X		0				X		1	0.5	TA
4.1.1.5	Start Solenoid Valve	1	0.502	0.025	X		0				X		1	0.8	X
4.1.1.6	Start He Pressure Switch	1	0.068	0.003	X		0				X		1	0.1	X
4.1.1.7	Igniter Oxidizer Supply Valve	1	0.027	0.001	X		0				X		1	0.1	X
4.1.1.8	Fuel Pump Discharge Cool Down Valve	1	0.001	-							X		1	0.05	X
4.1.1.9	Fuel Pump Interstage Cool Down Valve	1	0.001	-							X		1	0.05	X
4.1.1.10	Oxidizer Inlet Shutoff Valve	1	0.001	-							X		1	0.05	X
4.1.1.11	Fuel Inlet Shutoff Valve	1	0.001	-							X		1	0.05	X
4.1.1.12	Main Fuel Shutoff Valve	1	0.004	-							X		1	0.05	X
4.1.1.13	Gimbal Assembly	1	0.001	-							X		1	0.01	TA
4.1.1.14	Interstage Bleed and Pressure Release Valve	1	0.003	-							X		1	0.1	X
4.1.1.15	Sensors/Transducers	8	-												
4.1.1.15.1	Pressure	(4)	0.980	0.049	X		0						2	4.5	TA
4.1.1.15.2	Temperature	(3)	0.137	0.006	X		0						1	1	TA
4.1.1.15.3	Speed	(1)	0.001	-							X		1	0.1	TA
4.1.1.16	Fuel Tank Pressure Valve	(1)	0.001	-							X		1	0.1	X
4.1.1.17	Oxidizer Flow Control Valve	1	Units not Replaceable - Replace Engine and Overhaul												
4.1.1.18	Thrust Control Valve	1													
4.1.1.19	Oxidizer Pump	1													
4.1.1.20	Fuel Pump	1													
4.1.1.21	Cone	1													

Code - 1.1.1.1 ← Subassembly Level 8; Component Level 7; Assembly Level 6

Code	Functional Equipment (Assembly, Component, Subassembly)	Number Per Tug	Level I Maintenance: Failures Per 100 Flts	Level I Maintenance: Failures Per 5 Flts	Level I Maintenance: Replace Comp/LRU	Level I Maintenance: Repair Tug	Level I Maintenance: Component Initial Stock	Level I Maintenance: Component Float Stock (OPS)	Level II Maintenance: Subassy Failed/100 Flts	Level II Maintenance: Subassy Failed/5 Flts	Level II Maintenance: Replace Subassy	Level II Maintenance: Repair Component	Level II Maintenance: Subassy OPS Spares	Level II Maintenance: Subassy Repair Kits-Depot	Repair Subassy at Depot
4.1	Main Engine (Cont)														
4.1.2	Gimbal Actuators	2	0.09	0.005	X		0						1		
4.1.2.1	Motor Actuators	(4)							0.052	0.003	X		1	0.3	X
4.1.2.2	Magnetic Clutch	(4)							0.011	0.0005			0	0.015	X
4.1.2.3	Velocity Transducer	(4)							0.001	-			0	0.01	TA
4.1.2.4	Position Transducer	(4)							0.001	-			0	0.01	TA
4.1.2.5	Servo Amplifier	(4)							0.027	0.001	X		1	0.04	X
4.1.2.6	Ball Screw	(2)								-			0	0	X
4.1.2.7	Bellows	(2)								-			1	0.2	TA
4.1.2.8	Case Valve	(2)								-			0	0.2	TA
4.2	Main Engine Support														
4.2.1	Propellant Feed		(0.46)	0.023											
4.2.1.1	LH_2 Feedline Ball Valve	(1)	0.11	0.005	X		0						1	0.15	X
4.2.1.2	LO_2 Feedline Ball Valve	(1)	0.11	0.005	X		0						1	0.15	X
4.2.1.3	1/2-in. Check Valve	(2)	0.14	0.007	X		0						1	0.60	TA
4.2.1.4	Feedline Isolation Monitor	(2)	0.11	0.005	X		0						1	0.5	TA

Code - 1.1.1.1 — Subassembly Level 8; Component Level 7; Assembly Level 6

Code	Functional Equipment (Assembly, Component, Subassembly)	Number Per Tug	Level I Maintenance: Failures Per 100 Flts	Level I Maintenance: Failures Per 5 Flts	Level I Maintenance: Replace Comp/LRU	Level I Maintenance: Repair Tug	Level I Maintenance: Component Initial Stock	Level I Maintenance: Component Float Stock (OPS)	Level II Maintenance: Subassy Failed/ 100 Flts	Level II Maintenance: Subassy Failed/ 5 Flts	Level II Maintenance: Replace Subassy	Level II Maintenance: Repair Component	Level II Maintenance: Subassy OPS Spares	Level II Maintenance: Subassy Repair Kits-Depot	Repair Subassy at Depot
4.2	Main Engine Support														
4.2.2	Vent	1	1.43												
4.2.2.1	Isolation Valves LH_2	(4)	0.24	0.012	X		0						1	0.30	X
4.2.2.2	Tug Orbiter Fitting	(1)	0.07	0.003	X		0						1	0.13	X
4.2.2.3	Vent and Relief Valves	(2)	0.40	0.020	X		0						1	0.5	X
4.2.2.4	Isolation Valves LO_2	(4)	0.24	0.012	X		0						1	0.30	X
4.2.2.5	Tug Orbiter Fitting LO_2	(1)	0.07	0.003	X		0						1	0.13	X
4.2.2.6	Vent and Relief Valves LO_2	(2)	0.40	0.020	X		0						1	0.5	X
4.2.3	Fill and Drain (and Abort)	1	0.73												
4.2.3.1	Valve LH_2	(3)	0.36	0.018	X		0						1	0.50	X
4.2.3.2	Valve LO_2	(3)	0.36	0.018	X		0						1	0.50	X
4.2.3.3	Disconnect LH_2	(1)	0.003	0.001	X		0						1	0.01	X
4.2.3.4	Disconnect LO_2	(2)	0.006	0.001	X		0						1	0.02	X
4.2.4	Pneumatic	1	1.74												
4.2.4.1	Control Valve Modules	(22)	1.74	0.087	X		0						1	2.26	X
4.2.5	Propellant Utilization	1	0.52												
4.2.5.1	LH_2 Capacity Probe	(1)	0.06	0.003	X		0						1	0.08	X
4.2.5.2	LO_2 Capacity Probe	(1)	0.06	0.003	X		0						1	0.08	X
4.2.5.3	Propellant Utilization Assembly	(1)	0.39	0.020	X		0						1	0.52	X
4.2.5.4	Capacity Probe Attach/Gaskets	(2)	0.004	0.001	X		0						1	0.02	TA

Code	Code - 1.1.1.1 — Subassembly Level 8; Component Level 7; Assembly Level 6	Number Per Tug	Level I Maintenance						Level II Maintenance						Repair Subassy at Depot
	Functional Equipment (Assembly, Component, Subassembly)		Failures Per 100 Flts	Failures Per 5 Flts	Replace Comp/LRU	Repair Tug	Component Initial Stock	Component Float Stock (OPS)	Subassy Failed/ 100 Flts	Subassy Failed/ 5 Flts	Replace Subassy	Repair Component	Subassy OPS Spares	Subassy Repair Kits-Depot	
4.2	Main Engine Support														
4.2.6	Pressurization	1	0.47												
4.2.6.1	He Tanks	5	0.01	0.001	X		0						1	0.02	X
4.2.6.2	He Regulator	2	0.20	0.01	X		0						1	0.32	X
4.2.6.3	Shutoff Valves-Solenoid	6	0.24	0.01	X		0						1	0.32	X
4.2.6.4	Plenum	11	0.002	--	X		0						0	0.003	X
4.2.6.5	Relief Valve-Burst	1	0.004	--	X		0						1	0.02	TA
4.2.6.6	Fill Adapter	11	0.002	--	X		0						1	0.003	X
4.2.6.7	Tank Pressurization Orifice	3	0.011	0.001	X		0						1	0.05	TA
4.3	ACPS Engine														
4.3.1	ACPS Module	4	0.25	0.013	X		0						1		
4.3.1.1	R-30 Engine	(16)					0		0.06	0.004	X		1	0.12	X
4.3.1.2	Thrustor Isolation Valve	(16)					0		0.10	0.005	X		1	0.13	X
4.3.1.3	Thrustor Control Valve	(16)					0		0.10	0.005	X		1	0.13	X
4.4	ACPS Engine Support														
4.4.1	Tank	3	0.12	0.006	X		0						1	0.16	X
4.4.1.1	Tank Bladder	(3)	0.11	0.005									-	0.50	TA
4.4.2	Relief Valve	(1)	0.004	--	X		0						1	0.005	X
4.4.3	Fill Valve GN_2	(1)	0.04	0.002	X		0						1	0.05	X
4.4.4	Fill Fitting GN_2	(1)	--	--	X		0						1	--	X
4.4.5	Fill Valve N_2H_4	(1)	0.04	0.002	X		0						1	0.05	X
4.4.6	Fill Fitting N_2H_4	(1)	--	--	X		0						1	--	X
4.4.7	Screen Filter	(1)	--	--	X		0						1	--	X
4.4.8	Module Isolation Valve	(4)	0.16	0.008	X		0						1	0.21	X

Options 1 and 3I

IDENTIFICATION	CODE	NUMBER PER TUG	COMP SPARE COST ÷ COMP SHIPSET COST	COMP SPARE COST AS FRACTION OF ASSY COST	INITIAL SPARES - COMPONENTS	INITIAL COMP SPARES IN ESS*	AVG SUBASSY COST AS FRACTION OF ASSY COST	INITIAL SPARES - SUBASSYS	TOTAL INITIAL SPARES - SUBASSYS	INITIAL SUBASSY SPARES IN EES	TOTAL INITIAL SPARES IN EES	OPER SPARES - COMPONENTS	OPER COMP SPARES IN ESS	OPER SPARES - SUBASSYS	TOTAL OPER SPARES - SUBASSYS	OPER SUBASSY SPARES IN EES	TOTAL OPER SPARES IN EES	DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EES	TOTAL DEPOT SPARES IN EES
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
			R	C_i	SI_j	$R \cdot C_j SI_j$	F_i C_i/R_i	SI_i	ΣSI_i	$C_1 \Sigma SI_i$	EI	SO_j	$R \cdot C_j SO_j$	SO_i	ΣSO_i	$C_1 \Sigma SO_i$	EO	SD_i	ΣSD_i	$C_1 \Sigma SD_i$	ED
Structure	1.0										0						0.206				0.008
Fuel Tank	1.1	1	0.90	[0.48]			0.080						0.30			0.0002	0.130				0.0008
Access Gaskets	1.1.1	(5)												0.001	0.002			0.005	0.010		
Structure Repair Kit	1.1.2	(1)												0.001				0.005			
Oxidizer Tank	1.2	1	0.90	[0.19]			0.032						0.30			0.0001	0.051				0.0003
Access Gaskets	1.2.1	(5)												0.001	0.002			0.005	0.010		
Structure Repair Kit	1.2.2	(1)												0.001				0.005			
Body Structure	1.3	1	0.90	[0.13]			0.065						0.10			0.0046	0.012				0.0046
Paint	1.3.1	(1)												0.02	0.07			0.05	0.70		
Access Cover Panels	1.3.2	(1)												0.05				0.02			
Thrust Structure	1.4	1	0.90	[0.06]									0.10	0.10	0.10	0.0054	0.006				0.0018
Repair Kit	1.4.1	(1)																0.03	0.03		
Meteoroid Shield	1.5	1	0.90	[0.03]			0.015						0.10								0.0006
Repair Kit - Aluminum Sandwich	1.5.1	(1)												0.002	0.004	0.0001	0.003	0.02	0.04		
Repair Kit - FBCLS	1.5.2	(1)												0.002				0.02			
Payload Docking	1.6	1	0.90	[0.04]			0.0022						0.10		0.320	0.0007	0.004			0.0002	0.0002
Latches	1.6.1	4												0.05				0.01	0.084		
Latch Trigger	1.6.2	4												0.05				0.01			
Retract Cylinder	1.6.3	4												0.05				0.03			
Plumbing Kit	1.6.4	1												0.02				0.004			
Frame Tube	1.6.5	1												0.15				0.03			

*ESS - EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
IDENTIFICATION	CODE	NUMBER PER TUG	COMP SPARE COST ÷ COMP SHIPSET COST	COMP SPARE COST AS FRACTION OF ASSY COST	INITIAL SPARES – COMPONENTS	INITIAL COMP SPARES IN ESS*	AVG SUBASSY COST AS FRACTION OF ASSY COST	INITIAL SPARES – SUBASSYS	TOTAL INITIAL SPARES – SUBASSYS	INITIAL SUBASSY SPARES IN EES	TOTAL INITIAL SPARES IN EES	OPER SPARES – COMPONENTS	OPER COMP SPARES IN ESS	OPER SPARES – SUBASSYS	TOTAL OPER SPARES – SUBASSYS	OPER SUBASSY SPARES IN EES	TOTAL OPER SPARES IN EES	DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EES	TOTAL DEPOT SPARES IN EES
			R	C_i	SI_j	$R \cdot C_j \cdot SI_j$	C_i/N_i	SI_i	ΣSI_i	$C1\Sigma SI_i$	EI	SO_j	$R \cdot C_j \cdot SO_j$	SO_i	ΣSO_i	$C1\Sigma SO_i$	EO	SD_i	ΣSD_i	$C1\Sigma SD_i$	ED
Thermal Control	2.0										0						0.210				0.262
Tank Paint	2.1	1	0.90	[0.30]									0.1				0.10			(0.25)	0.25
Insulation Purge	2.2			[0.66]													0.11			(0.01)	0.012
Liner Repair Kit	2.2.1	1	0.90	0.01									0.01							(0.001)	
Plumbing	2.2.2	1	0.90	0.05									0.05							(0.001)	
Valves	2.2.3	2	0.90	0.001									0.05								

*ESS - EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

Options 1 and 1

IDENTIFICATION	1 CODE	2 NUMBER PER TUG	3 COMP SPARE COST ÷ COMP SHIPSET COST	4 COMP SPARE COST AS FRACTION OF ASSY COST	5 INITIAL SPARES – COMPONENTS	6 INITIAL COMP SPARES IN ESS*	7 AVG SUBASSY COST AS FRACTION OF ASSY COST	8 INITIAL SPARES – SUBASSYS	9 TOTAL INITIAL SPARES – SUBASSYS	10 INITIAL SUBASSY SPARES IN EES	11 TOTAL INITIAL SPARES IN EES	12 OPER SPARES – COMPONENTS	13 OPER COMP SPARES IN ESS	14 OPER SPARES – SUBASSYS	15 TOTAL OPER SPARES – SUBASSYS	16 OPER SUBASSY SPARES IN EES	17 TOTAL OPER SPARES IN EES	18 DEPOT REPAIR KITS IN EQUIV SUBASSYS	19 TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	20 TOTAL DEPOT REPAIR KITS IN EES	21 TOTAL DEPOT SPARES IN EES
			R	C_j	SI_j	$R \cdot C_j \cdot SI_j$	$\hat{C}_i/N_i$	SI_i	ΣSI_i	$C_1 \Sigma SI_i$	EI	SO_j	$R \cdot C_j \cdot SO_j$	SO_i	ΣSO_i	$C_1 \Sigma SO_i$	EO	SD_i	ΣSD_i	$C_1 \Sigma SD_i$	ED
Avionics	3.0										0.170						0.397				0.897
Data Management	3.1			[0.26]		(0.216)				(0.030)	0.064 (0.246)		(0.216)			(0.244)	(0.460) 0.120				2.198
Computer	3.1.1	1	0.90	0.24	1	0.216	0.048					1	0.216		3	0.144			6	0.288	
CPU	3.1.1.1													1				1.2			
Memory Stack	3.1.1.2													2				4.5			
Unit Misc (Box)	3.1.1.3													0				0.3			
Module I/F Unit	3.1.2	1	0.90	0 70			0.010		3	0.03					10	0.10			19.1	1.91	
Bus I/F Unit	3.1.2.1	10						0													
Power Control Unit	2	24						1													
Discrete Comm.	3	16						1													
Remote Mplx Unit	4	16						1													
Data I/F Unit	5	2						0													
Signal Cond Unit	6	4						0													
DCU	3.1.3	2						0													

*ESS - EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

IDENTIFICATION	1 CODE	2 NUMBER PER TUG	3 COMP SPARE COST ÷ COMP SHIPSET COST	4 COMP SPARE COST AS FRACTION OF ASSY COST	5 INITIAL SPARES – COMPONENTS	6 INITIAL COMP SPARES IN ESS*	7 AVG SUBASSY COST AS FRACTION OF ASSY COST	8 INITIAL SPARES – SUBASSYS	9 TOTAL INITIAL SPARES – SUBASSYS	10 INITIAL SUBASSY SPARES IN EES	11 TOTAL INITIAL SPARES IN EES	12 OPER SPARES – COMPONENTS	13 OPER COMP SPARES IN ESS	14 OPER SPARES – SUBASSYS	15 TOTAL OPER SPARES – SUBASSYS	16 OPER SUBASSY SPARES IN EES	17 TOTAL OPER SPARES IN EES	18 DEPOT REPAIR KITS IN EQUIV SUBASSYS	19 TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	20 TOTAL DEPOT REPAIR KITS IN EES	21 TOTAL DEPOT SPARES IN EES
			R	C_i	SI_i	$R \cdot C_i \cdot SI_i$	C_i/N_i	SI_i	ΣSI_i	$C1\Sigma SI_i$	EI	SO_j	$R \cdot C_j \cdot SO_j$	SO_i	ΣSO_i	$C1\Sigma SO_i$	EO	SD_i	ΣSD_i	$C1\Sigma SD_i$	ED
Avionics (Cont'd)	3.0																				
G, N & C	3.2			[0.05]		(0.12)					(0.12)		(0.09)			(0.28)	(0.37)				0.43
IMU	3.2.1	6	0.15	0.8	1	0.12	0.044			0	(0.006)		0		4	0.18	0.019		7.1	0.31	
Gyro Assy	3.2.1.1	(6)												1				2.0			
Accelerometers	3.2.1.2	(6)												1				0.2			
Sensor Electronics	3.2.1.3	(2)												1				1.5			
Power Supply Electronics	3.2.1.4	(2)																2.0			
Housing & Coolant	3.2.1.5	(2)												1				1.4			
Star Sensor	3.2.2	2	0.45	0.2	0	0.	0.050					1	0.09		2	0.10			2.4	0.12	
Sensor	3.2.2.1	(2)												1				2.0			
Stabilizer Drive	3.2.2.2	(2)												1				0.4			

*ESS EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

IDENTIFICATION	1 CODE	2 NUMBER PER TUG	3 COMP SPARE COST ÷ COMP SHIPSET COST	4 COMP SPARE COST AS FRACTION OF ASSY COST	5 INITIAL SPARES - COMPONENTS	6 INITIAL COMP SPARES IN ESS*	7 AVG SUBASSY COST AS FRACTION OF ASSY COST	8 INITIAL SPARES - SUBASSYS	9 TOTAL INITIAL SPARES - SUBASSYS	10 INITIAL SUBASSY SPARES IN EES	11 TOTAL INITIAL SPARES IN EES	12 OPER SPARES - COMPONENTS	13 OPER COMP SPARES IN ESS	14 OPER SPARES - SUBASSYS	15 TOTAL OPER SPARES SUBASSYS	16 OPER SUBASSY SPARES IN EES	17 TOTAL OPER SPARES IN EES	18 DEPOT REPAIR KITS IN EQUIV SUBASSYS	19 TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	20 TOTAL DEPOT REPAIR KITS IN EES	21 TOTAL DEPOT SPARES IN EES
			R	C_i	SI_j	$R \cdot C_j \cdot SI_j$	C_i/N_i	SI_i	ΣSI_i	$C_1 \Sigma SI_i$	EI	SO_j	$R \cdot C_j \cdot SO_j$	SO_i	ΣSO_i	$C_1 \Sigma SO_i$	EO	SD_i	ΣSD_i	$C_1 \Sigma SD_i$	ED
Communications	3.3			[0.53]		(0.189)				(0)	(0.189)		(0)			(0.442	(0.442)			(0.566)	0.566
											0.100						0.234				
Antenna	3.3.1	4	0.225	0.05	0									1		0.011		0.3		0.003	
Multiplexer	3.3.2	[illegible]	0.90	0.11	0									1		0.099		0.3		0.030	
Power Amp	3.3.3	1	0.90	0.11	1	0.099								1		0.099					
TWT	3.3.3.1	(4)					0.022							2	3	0.066		9.0	9.3	0.205	
Circuitry	3.3.3.2	(1)												1				0.3			
Transponder	3.3.4	2	0.45	0.11	0									1		0.050					
PC Board	3.3.4.1	(4)					0.018							1	1	0.018		0.4	0.5	0.009	
Component Circuits	3.3.4.2	(2)												0				0.1			
Command Decoder	3.3.5	2	0.45	0.11	0									2		0.099		0.3		0.015	
Processor	3.3.6	1	0.90	0.20	0									1		0.180					
PC Boards	3.3.6.1	(2)					0.067							1	1	0.067		0.4	0.6	0.040	
Circuitry	3.3.6.2	(1)																0.2			
Command Encoder	3.3.7	1	0.90	0.11	0									1		0.099		1.0		0.099	
Tape Recorders	3.3.8	2	0.45	0.20	1	0.090												0.5		0.045	
Tape Drive Mechanical	3.3.8.1	(2)					0.033							1	2	0.066		0.6	3.6	0.120	
Magnetic Heads	3.3.8.2	(2)												1				1.0			
Electronics	3.3.8.3	(2)																2.0			

*ESS - EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
IDENTIFICATION	CODE	NUMBER PER TUG	COMP SPARE COST ÷ COMP SHIPSET COST	COMP SPARE COST AS FRACTION OF ASSY COST	INITIAL SPARES - COMPONENTS	INITIAL COMP SPARES IN ESS*	AVG SUBASSY COST AS FRACTION OF ASSY COST	INITIAL SPARES - SUBASSYS	TOTAL INITIAL SPARES - SUBASSYS	INITIAL SUBASSY SPARES IN EES	TOTAL INITIAL SPARES IN EES	OPER SPARES - COMPONENTS	OPER COMP SPARES IN ESS	OPER SPARES - SUBASSYS	TOTAL OPER SPARES - SUBASSYS	OPER SUBASSY SPARES IN EES	TOTAL OPER SPARES IN EES	DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EES	TOTAL DEPOT SPARES IN EES
			R	C_j	S_{Ij}	$R \cdot C_j \cdot S_{Ij}$	C_i/N_i	S_{Ii}	ΣS_{Ii}	$C_i \Sigma S_{Ii}$	E_I	S_{Oj}	$R \cdot C_j \cdot S_{Oj}$	S_{Oi}	ΣS_{Oi}	$C_i \Sigma S_{Oi}$	E_O	S_{Di}	ΣS_{Di}	$C_i \Sigma S_{Di}$	E_D
Instrumentation	3.4			[0.06]		(0)				(0)	0		(0)			(0.313)	(0.313)			(0.005)	0.005
Sensors	3.4.1	1	0.90	0.45	0												0.019				
Strain	3.4.1.1	(10)					0.005							3	33	0.175		0.1	0.7	0.004	
Pressure Transducers	3.4.1.2	(25)												10				0.1			
Temperature Transducers	3.4.1.3	(30)												10				0.2			
Position Sensors	3.4.1.4	(20)												10				0.3			
Signal Conditioning	3.4.2	1	0.90	0.45																	
Signal Conditioning Units	3.4.2.1	(65)					0.007							20	20	0.138		0.1		0.001	
Circuitry	3.4.3			0.10																	
Elect. Power Source	3.5	1		[0.01]							0					(0.288)	(0.288)				0
Batteries - Ag/Zn	3.5.1	2	0.45	0.85										0.4		0.153	0.003				
Batteries - TVC	3.5.2	1	0.90	0.15										1		0.135					
Power Distribution	3.6	1		[0.03]							0					(0.083)	(0.083)			(0.138)	0.138
Motor-Driven Switches	3.6.1	(4)	0.225	0.20										1		0.045	0.002	0.5		0.23	
Relays	3.6.2	(14)	0.064	0.20										3		0.038		6.5		0.083	
Busses & Circuitry Kit	3.6.3	(1)	0.90	0.02	0													1.8		0.032	

*ESS EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

Options 1 and 3I

IDENTIFICATION	1 CODE	2 NUMBER PER TUG	3 COMP SPARE COST ÷ COMP SHIPSET COST	4 COMP SPARE COST AS FRACTION OF ASSY COST	5 INITIAL SPARES - COMPONENTS	6 INITIAL COMP SPARES IN ESS*	7 AVG SUBASSY COST AS FRACTION OF ASSY COST	8 INITIAL SPARES - SUBASSYS	9 TOTAL INITIAL SPARES - SUBASSYS	10 INITIAL SUBASSY SPARES IN EES	11 TOTAL INITIAL SPARES IN EES	12 OPER SPARES - COMPONENTS	13 OPER COMP SPARES IN ESS	14 OPER SPARES - SUBASSYS	15 TOTAL OPER SPARES - SUBASSYS	16 OPER SUBASSY SPARES IN EES	17 TOTAL OPER SPARES IN EES	18 DEPOT REPAIR KITS IN EQUIV SUBASSYS	19 TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	20 TOTAL DEPOT REPAIR KITS IN EES	21 TOTAL DEPOT SPARES IN EES Note 1
			R	Cj	SIj	R·Cj·SIj	Ci/Ni	SIi	ΣSIi	C1ΣSIi	EI	SOj	R·Cj·SOj	SOi	ΣSOi	C1ΣSOi	EO	SDi	ΣSDi	C1ΣSDi	ED
Propulsion	4.0										0.162						0.419				0.061
Main Engine	4.1			[0.19]		0.855				0	(0.855)						(0.647)				(0.158)
Engine	4.1.1	1	0.90	0.95	1	0.855	0.0413				0.162				15	0.620	0.123		2.96	0.122	
Igniter	4.1.1.1	1												1				0.1			
Ignition Exciter	4.1.1.2	1												1				0.1			
Prestart Solenoid Valve	4.1.1.3	1												1				0.8			
Prestart He Pressure Switch	4.1.1.4	1												1				0.5			
Start Solenoid Valve	4.1.1.5	1												1				0.8			
Start He Pressure Switch	4.1.1.6	1												1				0.1			
Igniter Oxid Supply Valve	4.1.1.7	1												1				0.1			
Fuel Pump Disch. Cool Down Valve	4.1.1.8	1												1				0.05			
F. P. Interstage Cool Down Valve	4.1.1.9	1												1				0.05			
Oxidizer Inlet S/O Valve	4.1.1.10	1												1				0.05			
Fuel Inlet S/O Valve	4.1.1.11	1												1				0.05			
Main Fuel S/O Valve	4.1.1.12	1												1				0.05			
Gimbal Assy	4.1.1.13	1												1				0.01			
Interstage Bleed & PR Valve	4.1.1.14	1												1				0.1			
Sensors/Transducers	4.1.1.15	8					(0.0052)								(4)	0.021			(6.6)	0.034	
Pressure	4.1.1.15.1	(4)												2				4.5			
Temperature	4.1.1.15.2	(3)												1				1.0			
Speed	4.1.1.15.3	(1)												1				0.1			
Fuel Tank Pressure Valve	4.1.1.16	1												1				0.1			
4.1.1.17 - 4.1.1.21 No Maintenance Possible																					

Note 1 Main Engine Omitted for Depot.

*ESS - EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
IDENTIFICATION	CODE	NUMBER PER TUG	COMP SPARE COST ÷ COMP SHIPSET COST	COMP SPARE COST AS FRACTION OF ASSY COST	INITIAL SPARES - COMPONENTS	INITIAL COMP SPARES IN ESS*	AVG SUBASSY COST AS FRACTION OF ASSY COST	INITIAL SPARES - SUBASSYS	TOTAL INITIAL SPARES - SUBASSYS	INITIAL SUBASSY SPARES IN EES	TOTAL INITIAL SPARES IN EES	OPER SPARES - COMPONENTS	OPER COMP SPARES IN ESS	OPER SPARES - SUBASSYS	TOTAL OPER SPARES - SUBASSYS	OPER SUBASSY SPARES IN EES	TOTAL OPER SPARES IN EES	DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EES	TOTAL DEPOT SPARES IN EES
			R	C_i	SI_i	$R \cdot C_i \cdot SI_i$	$\bar{C}_i/N$	SI_i	ΣSI_i	$C1 \Sigma SI_i$	EI	SO_i	$R \cdot C_i \cdot SO_i$	SO_i	ΣSO_i	$C1 \Sigma SO_i$	EO	SD_i	ΣSD_i	$C1 \Sigma SD_i$	ED
Gimbal Actuators	4.1.2	2	0.45	0.05	0						0	1	0.023								
Motor Actuators	4.1.2.1	(4)					0.0019							1	3	0.0058		0.3	0.91	0.0018	
Magnetic Clutch	4.1.2.2	(4)												0				0.15			
Velocity Transducer	4.1.2.3	(4)												0				0.01			
Position Transducer	4.1.2.4	(4)												0				0.01			
Servo Amplifier	4.1.2.5	(4)												1				0.04			
Ball Screw	4.1.2.6	(2)												0				0			
Bellows	4.1.2.7	(2)												1				0.2			
Case Valve	4.2.1.8	(2)												0				0.2			

*ESS - EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

IDENTIFICATION	CODE (1)	NUMBER PER TUG (2)	COMP SPARE COST ÷ COMP SHIPSET COST (3)	COMP SPARE COST AS FRACTION OF ASSY COST (4)	INITIAL SPARES – COMPONENTS (5)	INITIAL COMP SPARES IN ESS* (6)	AVG SUBASSY COST AS FRACTION OF ASSY COST (7)	INITIAL SPARES – SUBASSYS (8)	TOTAL INITIAL SPARES – SUBASSYS (9)	INITIAL SUBASSY SPARES IN EES (10)	TOTAL INITIAL SPARES IN EES (11)	OPER SPARES – COMPONENTS (12)	OPER COMP SPARES IN ESS (13)	OPER SPARES – SUBASSYS (14)	TOTAL OPER SPARES – SUBASSYS (15)	OPER SUBASSY SPARES IN EES (16)	TOTAL OPER SPARES IN EES (17)	DEPOT REPAIR KITS IN EQUIV SUBASSYS (18)	TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS (19)	TOTAL DEPOT REPAIR KITS IN EES (20)	TOTAL DEPOT SPARES IN EES (21)
			R	C_j	S_{ij}	$R \cdot C_j \cdot S_{ij}$	C_i/N_i	S_i	ΣS_i	$C_1 \Sigma S_i$	EI	SO_j	$R \cdot C_j \cdot SO_j$	SO_i	ΣSO_i	$C_1 \Sigma SO_i$	EO	SD_i	ΣSD_i	$C_1 \Sigma SD_i$	ED
Main Engine Support	4.2			[0.53]		0				0	0					0.459	(0.459) 0.243				(C.1[illegible]
Propellant Feed	4.2.1	1	0.90	0.20		0	0.033								4.0	0.133			1.40	0.047	
LH_2 Feedline Ball Valve	4.2.1.1	(1)			0			0						1				0.15			
LO_2 Feedline Ball Valve	4.2.1.2	(1)			0			0						1				0.15			
1/2 In. Check Valve	4.2.1.3	(2)			0			0						1				0.60			
Feedline Isolation Monitor	4.2.1.4	(2)			0			0						1				0.50			
Vent	4.2.2	1	0.90	0.10		0	0.007								6	0.043			1.86	0.013	
LH_2 Isolation Valves	4.2.2.1	(4)			0			0						1				0.30			
Tug-Orbiter Fitting LH_2	4.2.2.2	(1)			0			0						1				0.13			
Vent & Relief Valves	4.2.2.3	(2)			0			0						1				0.50			
LO_2 Isolation Valves	4.2.2.4	(4)			0			0						1				0.30			
T-O Fitting LO_2	4.2.2.5	(1)			0			0						1				0.13			
V & R Valves LO_2	4.2.2.6	(2)			0			0						1				0.50			
Fill, Drain, Abort	4.2.3	1	0.90	0.15		0	0.017								4	0.068					
LH_2 Valve	4.2.3.1	(3)			0			0						1				0.50			
LO_2 Valve	4.2.3.2	(3)			0			0						1				0.50			
LH_2 Disconnect	4.2.3.3	(1)			0			0						1				0.01			
LO_2 Disconnect	4.2.3.4	(2)			0			0						1				0.02			
Pneumatic	4.2.4	1	0.90	0.10		0	0.005								1	0.005			2.26	0.010	
Control Valve Mods	4.2.4.1	22			0			0						1				2.26			

*ESS – EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

IDENTIFICATION	1 CODE	2 NUMBER PER TUG	3 COMP SPARE COST / COMP SHIPSET COST	4 COMP SPARE COST AS FRACTION OF ASSY COST	5 INITIAL SPARES - COMPONENTS	6 INITIAL COMP SPARES IN ESS*	7 AVG SUBASSY COST AS FRACTION OF ASSY COST	8 INITIAL SPARES - SUBASSYS	9 TOTAL INITIAL SPARES - SUBASSYS	10 INITIAL SUBASSY SPARES IN EES	11 TOTAL INITIAL SPARES IN EES	12 OPER SPARES - COMPONENTS	13 OPER COMP SPARES IN ESS	14 OPER SPARES - SUBASSYS	15 TOTAL OPER SPARES - SUBASSYS	16 OPER SUBASSY SPARES IN EES	17 TOTAL OPER SPARES IN EES	18 DEPOT REPAIR KITS IN EQUIV SUBASSYS	19 TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	20 TOTAL DEPOT REPAIR KITS IN EES	21 TOTAL DEPOT SPARES IN EES
			R	C_i	SI_j	$R \cdot C_j SI_j$	C_i/N_i	SI_i	ΣSI_i	$C1 \Sigma SI_i$	EI	SO_j	$R \cdot C_j SO_j$	SO_i	ΣSO_i	$C1 \Sigma SO_i$	EO	SD_i	ΣSD_i	$C1 \Sigma SD_i$	ED
Main Engine Support (Cont'd)	4.2 (Cont'D)																				
Propellant Utilization	4.2.5	1	0.90	0.15			0.030								4	0.120			0.70	0.021	
LH_2 Capacitor Probe	4.2.5.1	(1)			0			0						1				0.08			
LO_2 Capacitor Probe	4.2.5.2	(1)			0			0						1				0.08			
Propellant Utilization Assy	4.2.5.3	(1)			0			0						1				0.52			
Capacitor PR Attach Gasket	4.2.5.4	(2)			0			0						1				0.02			
Pressurization	4.2.6	1	0.90	0.30			0.015								6	0.090			0.686	0.010	
He Tanks	4.2.6.1	(6)			0			0						1				0.02			
He Reg	4.2.6.2	(2)			0			0						1				0.27			
Solenoid S/O Valves	4.2.6.3	(6)			0			0						1				0.32			
Plenum	4.2.6.4	(1)			0			0						0				0.003			
Burst Relief Valve	4.2.6.5	(1)			0			0						1				0.02			
Fill Adapter	4.2.6.6	(1)			0			0						1				0.003			
Tank Pressure Orifice	4.2.6.7	(3)			0			0						1				0.05			

*ESS - EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

IDENTIFICATION	1 CODE	2 NUMBER PER TUG	3 COMP SPARE COST ÷ COMP SHIPSET COST	4 COMP SPARE COST AS FRACTION OF ASSY COST	5 INITIAL SPARES – COMPONENTS	6 INITIAL COMP SPARES IN EIS*	7 AVG SUBASSY COST AS FRACTION OF ASSY COST	8 INITIAL SPARES – SUBASSYS	9 TOTAL INITIAL SPARES – SUBASSYS	10 INITIAL SUBASSY SPARES IN EES	11 TOTAL INITIAL SPARES IN EES	12 OPER SPARES – COMPONENTS	13 OPER COMP SPARES IN EES	14 OPER SPARES – SUBASSYS	15 TOTAL OPER SPARES – SUBASSYS	16 OPER SUBASSY SPARES IN EES	17 TOTAL OPER SPARES IN EES	18 DEPOT REPAIR KITS IN EQUIV SUBASSYS	19 TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	20 TOTAL DEPOT REPAIR KITS IN EES	21 TOTAL DEPOT SPARES IN EES
			R	C_i	SI_i	$R \cdot C_i \cdot SI_i$	C_i/N_i	SI_i	ΣSI_i	$C1 \Sigma SI_i$	EI	SO_i	$R \cdot C_i \cdot SO_i$	SO_i	ΣSO_i	$C1 \Sigma SO_i$	EO	SD_i	ΣSD_i	$C1 \Sigma SD_i$	ED
ACPS Engine	4.3			[0.09]		0					0						(0.083) 0.007				(0.006)
ACPS Module	4.3.1	4	0.225	1.0	0		0.021					1			4	0.083			0.38	0.008	
MR-3C Engine	4.3.1.1	(8)			0									1				0.06			
R-30 Engine	4.3.1.2	(8)			0									1				0.06			
Thruster Isolation Valve	4.3.1.3	(16)			0									1				0.13			
Thruster Control Valve	4.3.1.4	(16)			0									1				0.13			
ACPS Engine Support	4.4			[0.15]							0						(0.300) 0.045				(0.044)
Tank	4.4.1	3	0.30	0.50	0	$\left(\frac{0.100}{3} = 0.033\right)$		0						1		0.150		0.160		0.024	
Tank Bladder	4.4.1.1	(3)												0				0.500		0.016	
Relief Valve	4.4.2	1		0.10	0			0						1		0.030		0.005		0.0002	
Fill Valve - GN_2	4.4.3	1		0.10	0			0						1		0.030		0.050		0.0015	
Fill Fitting - GN_2	4.4.4	1		0.04	0			0						1		0.012					
Fill Valve - N_2H_4	4.4.5	1		0.10	0			0						1		0.030		0.050		0.0015	
Fill Fitting - N_2H_4	4.4.6	1		0.04	0			0						1		0.012					
Screen Filter	4.4.7	1		0.02	0			0						1		0.006					
Modified Isolation Valve	4.4.8	4		0.10	0			0						1		0.030		0.021		0.0006	

* Estimated at .20 of tank cost

*EES - EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL 2 & 3F

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability: Parameter	% Risk	Method	Locat	Test	No. Test	No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
1.	Structure			100									.251	
1.1	Fuel Tank													
1.1.1	Access Cover Gaskets		Leakage	67	Hold Pressure	1.2.1	X		2		5		.025	
	Tank Repair Kit		Struct. Damage	33	Visual	1.1.7		X					.015	
1.2	LOX Tank													
1.2.1	Access Cover Gaskets		Leakage	67	Hold Pressure	1.2.1	X		2		5		.025	
	Tank Repair Kit		Struct. Damage	33	Visual	1.1.7		X					.015	
1.3	Body Struct.													
1.3.1	Paint		Appearance	60	Visual	1.1.7		X			5		.040	
1.3.2	Access Cover Panels		Tears/Cracks	40	Visual	1.1.7		X	4		5		.025	
1.4	Thrust Struct.													
1.4.1	Supports		Distortion	100	Visual	1.1.7		X			5		.013	
1.5	Meteoroid Shield													
1.5.1	Shell Repair Kit		Punctures	50	Visual	1.1.6		X			100		.065	
1.5.2	Repair Kit - Fbglas.		Punctures	50	Visual	1.1.6		X			100		.065	

C-38

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: 2 & 3F

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability: Parameter	% Risk	Method	Locat	Test	No. Test	No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NAKT	Attrib. Items R
1.6	Payload Docking												.033878	
1.6.1	Latch (Adjust)	Part	No Binding		Actuate	2.2.3	X		4			1 1	.004	
1.6.2	Latch Trigger (Adjust)	Part	Lock, Binding		Actuate	2.2.3	X		4			1 1	.004	
1.6.3	Retract Cylinder	Part	Release Latches		Actuate	2.2.3	X		4	3.0	5 100	5 1	.007200	
1.6.4	He Valves	Yes	Actuate Ret. Cyl.		Actuate	2.2.3	X		2	1.0	5	15 178	.001930	
1.6.5	Docking Ring Assy	Yes	Struct. Sound		Visual	2.2.3	X		1		1	178	.000200	
1.6.6	Energy Absorbers	Part	No Leakage		Visual	2.2.3	X		8	3.0	5 50	5 1	(.007200)	
1.6.7	Check Valves	No	Check Flow		Observ. Load	2.2.3	X		8	.27	5	1	(.000011)	
1.6.8	3 Position Gang Valve	Yes	Open/Vent		Observ. Load	2.2.3	X		1	3.0	5	10 178	(.002820)	
1.6.8.1	Solenoid Actuators	Yes	Position Valve		Gang Vlv Opn	2.2.3	X		2	(2.0)	5	1	(.000020)	
1.6.9	Vent/Relief Valve	Yes	Vent He		Calib.	1.1.7		X	1	1.0	5	10 178	(.000940)	
1.6.10	Tank	Yes	(In Pneumatics)						1	-	-	-	-	
1.6.11	Regulator	Yes	Cont. Press		Monitor Press.	2.4.2	X		1	2.5	5	10 178	(.002350)	
1.6.12	Hyd Accum	Yes	Store Hyd Fld		Monitor Press.		X		1	1.34	5	10 178	(.001260)	

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: 2 & 3F

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability						No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
			Parameter	% Risk	Method	Locat	Test	No. Test						
1.6.13	Spin up Drive Assy	No	Rotate S/c	-	Test Drive	1.1.7		X	2	12.8	5	.5	(.000064)	
1.6.14	Spin up Drive Idler	No	Position S/C	-	Test Opn.	1.1.7		X	1	.01	5	.5	(.000064)	
1.6.15	Pneumatic Actuator	No	Engage Drive	-	Test Opn.	1.1.7		X	3	3.0	5	.5	(.000023)	
1.6.16	Pneumatic Cont. Module	No.	Open/Close		Test Opn.	1.1.7		X	1	2.0	5	10 178	(.001880)	

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: 2 & 3F

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability						No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
			Parameter	% Risk	Method	Locat	Test	No. Test						
2.1	Insulation													
2.1.1	Repair Kit (MLI)		No Holes		Cold spots	1.1.4	X						.030	Est.
					Visual	1.1.6	X							
2.2	Insul. Purge Syst.										5		.112010	
2.2.1	Liner Repair Kit		Leakage		Press Test	1.1.7	X		1		5		.0300	
2.2.2	Vent Valves		Open		Flow Rate	1.1.7	X		3	1.0	5	10	.000150	
2.2.3	Regulator		He Press		Calib.	1.1.7	X		1	2.7	5	10 177	.025245	
2.2.4	Press Controller		Bag Press		Calib.	1.1.7	X		1	5.9	5	10 177	.055165	
2.2.5	Valves - Solenoid		Open/Close		F ow Test	1.1.7	X		1	1.0	5	10 177	.000935	
2.2.6	Relief Valve		Hold Press		Monitor Press	2.4.2	X		1	.5	5	10 177	.000468	
2.2.7	He Bottle		Hold Press		Monitor Fill	2.4.2	X		1	.05	5	10 177	.000047	

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: 2 & 3F

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability						No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
			Parameter	% Risk	Method	Locat	Test	No. Test						
3.1	Data Mgmt	2A		Est. 84		1							.687848	
3.1.1	Computer			Est. 98	Computer				1/2	125	7	15 158	.151375	
3.1.1.1	Central Process	Yes	Collect & Proc Data		Subroutines	2.4.1	X		1	20	7		(.024220)	
3.1.1.2	Memory Stack	Yes	Integrate Data		Subroutines	2.4.1	Part.		4	25	7		(.121100)	
3.1.1.3	Box-Misc	Yes	Computer Function		Subroutines	2.4.1	X		1	5	7		(.006055)	
3.1.2	Mod Interface Unit			Est. 80	Computer				1				.397708	
3.1.2.1	BIU	Yes	Pick up Bus Data		Subroutines	2.4.1	Part		10	4	7	15 158	(.048440)	
3.1.2.2	PCC	Yes	Power Control		Subroutines	2.4.1	Part		24	4	7		(.116256)	
3.1.2.3	DCU	Yes	Transfer Command		Subroutines	2.4.1	Part		20	4	7		(.096880)	
3.1.2.4	RMU	Yes	Multiplex Data		Subroutines	2.4.1	Part		20	4	7		(.096880)	
3.1.2.5	DIU	Yes	Transfer Data		Subroutines	2.4.1	Part		2	4	7		(.009688)	
3.1.2.6	SCU	Yes	Proper Measure.		Subroutines	2.4.1	Part		6	4	7		(.039064)	
3.1.3	DCU	Yes		Est. 80	Subroutines	2.4.1	Part		1/2	40	7	15 158	.048440	

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: 2 & 3F

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability: Parameter	% Risk	Method	Locat	Test	No. Test	No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
3.1.5	Computer Interface Unit	Yes	Computer Opn	Est. 100	Computer Software	2.3.9	X		1	5	7	15 158	.006055	
3.1.6	Inst. Power Supplies	Yes	Proper Voltage	Est. 100	Computer Software	2.3.9	X		6	5	7	15 158	.036330	
3.1.7	System Control Unit	Yes	Commd. Data	Est. 100	Computer Software	2.3.9	X		1/3	40	7	15 158	.048440	
3.1.7.1	PC Board A					2.3.9	X		(6)	(8)	7		(.019376)	
3.1.7.2	PC Board B					2.3.9	X		(6)	(10)	7		(.024220)	
3.1.7.3	Box Misc					2.3.9	X		(3)	(4)	7		(.004844)	

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: 2 & 3F

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability: Parameter	% Risk	Method	Locat	Test	No. Test	No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items $
3.2	GNC	3C		Est. 66.6									.547520	
3.2.1	IMU	x		71.4					1/2	420	8	2 148	.504000	
3.2.1.1	Gyros	Yes	Stabilize	57.2	Meas. Speed	2.4.4	X		(6)	80	8	2 148	(.288000)	
3.2.1.2	Accelerometers	Yes	Displacement	28.6	Bench Test	1.1.13		X	(6)	140	8	2 148	(.144000)	
3.2.1.3	Sensor Electronics	Yes	Input-Output Data	5.7	Operating Data	2.4.4	X		(2)	24	8	2 148	(.028800)	
3.2.1.4	Power Supply & Elect.	Yes	Power to Units	4.8	Unit Funct.	2.4.4	X		(2)	20	8	2 148	(.024000)	
3.2.1.5	Housing Assy & Coolant	Yes	Tempt. Cont.	3.8	Measure-TM	2.4.4	X		(2)	16	8	2 148	(.019200)	
3.2.2	Star Tracker			16					1/2	30	8	148	.035520	
3.2.2.1	Sensor	No	Sense/Track Stars	84.0	Light Table	1.1.13		X	(2)	(25)	8	148	(.029600)	
3.2.2.2	Stabiliz. Drive	No	Control Sensor Posit.	16.0	Test Response	1.2.1	X		(2)	(5)	8	148	(.005920)	
3.2.3	Docking Radar												.008000	
3.2.3.1	Laser Radar	No	Beam Dir.		Calibrate	1.1.7		X	1	200	8	5	(.008000)	

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: 2 & 3F

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability						No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
			Parameter	% Risk	Method	Locat	Test	No. Test						
3.3	Communications	B		Est. 99.2									.237170	
3.3.1	Omni Antenna	x	Data Output	100	Test For TM	2.4.1	X		4	3.6	8	15/148	.018778	
3.3.2	R.F. Multiplexer	x	Sequence Data	100	Test for TM	2.4.1	X		1	4.0	8	15/148	.005216	
3.3.3	Power Amplifier	x		100			X		1	49	8	15/148	.063896	
3.3.3.1	TWT		Voltage		Monitor by TM	2.4.1	X		(4)	(11)	8		(.057376)	
3.3.3.2	Circuitry		Power Avail.		TM Communic.	2.4.1	X		(1)	(5)	8		(.006520)	
3.3.4	Transponder (SGLS)	x	Relay Data	100	Interrog.	1.1.13		X	1	10	8	5/148	.012240	
3.3.4.1	PC Board								2	4	8	5/148	(.009792)	
3.3.5	Command Decoder	x	Equip. Function	100	TM Command	2.4.1	X		1	10	8	15/148	.013040	
3.3.6	Processor (Mod/Demod)	x		85			Part		1	10	8	15/148	.013040	
3.3.6.1	PC Boards		Data Input to TM		Interrog. TM	2.4.1	Part		2	4	8	15/148	(.010432)	
3.3.6.2	Circuitry		Data Input to TM		Interrog. TM		Part		1	2	8	15/148	(.002608)	
3.3.7	PCM Encoder	x	Equip. Funct.	100	TM Command	2.4.1	X		1	10	8	15/148	.013040	

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: 2 & 3F

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability: Parameter	% Risk	Method	Locat	Test	No. Test	No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
3.3.8	Tape Recorder	x		100				X	2	30	8	5 148	.073440	
3.3.8.1	Tape Drive Mech		Position Tape		Oper T.R.	2.4.1			2	6	8	5 148	(.014688)	
3.3.8.2	Magnetic Heads		Read/Energize Tape		Oper T.R.	2.4.1			2	2	8	5 148	(.004896)	
3.3.8.3	Electronics		Control Functions		Oper T.R.	2.4.1			2	22	8	5 148	(.053856)	

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: 2

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability: Parameter	% Risk	Method	Locat	Test	No. Test	No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
3.3.10	Comsec Equip	No	Req Response	100	TM Data	2.3.9	X		1	10	8	5 148	.012240	
3.3.11	Transponder (STDN)	No	Relay Data	100	TM Data	2.4.1	X		1	10	8	5 148	.012240	
3.3.11.1	PC Board								2	4			(.009792)	
3.4	Instrumentation	(Limited)		Est. 94.6									.198495	
3.4.1	Sensors	x		99.1							8		.168495	
	Strain	Yes	Continuity		Test software	1.2.1		X	10	.05	8	1 148	(.000775)	
	Press. Transducers	Yes	Press Actuation		Loading Opns	2.4.2	X		25	.1	8	2 148	(.003000)	
	Temp. Transducers	Yes	Temp Actuation		Loading Opns	2.4.2	X		30	3	8	15 148	(.117360)	
	Position Sensors	Yes	Position Indic.		Checkout	1.2.1	Part.		20	2	8	148	(.047360)	
3.4.2	Signal Conditioning	x		Est. 85					1	25	8	2 148	(.030000)	
	Misc.	Yes	Signal Char.		Test Software				65	.3	8			
3.5	Elect. Power			99.7									.059711	
3.5.1	Fuel Cell PP	Yes	Power Output	99.4	Monitor Volts	2.4.4	X		1/2				.026597	
3.5.1.1	Power Cell Stack	Yes	Reactant Flow	74.2	Monitor Volts	2.4.4	X		1/2	26.5	5	149	(.019743)	
3.5.1.2	Reactant Cont. Valves	Yes	Open/Close	5.6	Press. Sens.	2.4.4	X		4	1.0	5	149	(.001490)	

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL 2

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability						No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
			Parameter	% Risk	Method	Locat	Test	No. Test						
3.5.1.3	Coupled Regulators	Yes	Pressure	14.0	Monitor Inst.	2.4.4	X		4	2.5	5	149	(.003725)	
3.5.1.4	Reactant Scrubbers	Yes	Remove Contam.	0.6	Press. Sens.	2.4.4		X	4	0.1	5	149	(.000149)	
3.5.1.5	Vent Valves	Yes	Press. Relief	5.6	Monitor Cycle	2.4.4	X		4	1.0	5	149	(.001490)	
3.5.2	Fuel Cell Reactant Syst.			100									.021114	
3.5.2.1	O_2 Tank	Yes	Leaks		Monitor Press.	2.4.2	X		1	.05	5	10 177	(.000047)	
3.5.2.2	N_2 Tank	Yes	Leaks		Monitor Press.	2.4.2	X		1	.05	5	10 177	(.000047)	
3.5.2.3	O_2 Fill Valve	Yes	Open/Close		Fill Cycle	2.4.2	X		1	1.0	5	10 177	(.000935)	
3.5.2.4	O_2 Vent/ Relief Valve	Yes	Setting		Monitor Press	2.4.2	X		1	4.34	5	10 177	(.004058)	
3.5.2.5	H_2 Fill Valve	Yes	Open/Close		Fill Cycle	2.4.2	X		1	1.0	5	10 177	(.000935)	
3.5.2.6	H_2 Vent/Relief Valve	Yes	Setting		Monitor Press.	2.4.2	X		1	4.34	5	10 177	(.004058)	
3.5.2.7	O_2 Tank Press. Cage	Yes	Function		Monitor Press.	2.4.2	X		1	5.9	5	10 177	(.005517)	
3.5.2.8	H_2 Tank Press. Cage	Yes	Function		Monitor Press.	2.4.2	X		1	5.9	5	10 177	(.00517)	

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: 2

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability						No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
			Parameter	% Risk	Method	Locat	Test	No. Test						
3.5.3	Primary Battery	Yes	Power Avail	100	Final C/O	2.4.4	X		1	10	8	2 148	.012000	
			Replace after each flt.											
3.6	Power Distribution			100		2.4.4			1				.007824	
3.6.1	Power Dist. Components	Yes	Power Avail		Use in C/O	2.4.4			10	.5	8	15 148	(.006520)	
3.6.2	Wire Harnesses & Bus	Yes	Power Avail		Use in C/O	2.4.4			10	.1	8	15 148	(.001304)	

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: 2 & 3F

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability: Parameter	% Risk	Method	Locat	Test	No. Test	No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
4.0	Propulsion													
4.1	Main Engine			0										
4.1.1	Main Engine			0						14000	8	.50	.056000	(.034237) Compon.
4.1.1.1	Igniter		Energy Avail		Excite	1.1.7		X	1	20.0	5	.50	(.000050)	
4.1.1.2	Ignition Exciter		Energy Avail		Apply Power	1.1.7		X	1	5.0	8	.50	(.000020)	
4.1.1.3	Prestart Solenoid Vlv		Open/Close		Act.-Posit. Sens.	1.1.7		X	1	11.0	8	57	(.005016)	
4.1.1.4	Prestart He Press. Sw.		Open/Close		Act.-Posit. Sens.	-		X	1	1.5	8	57	(.000684)	
4.1.1.5	Start Solenoid Vlv		Open/Close		Act.-Posit. Sens.	1.1.7		X	1	11.0	8	57	(.005016)	
4.1.1.6	Start He Press. Sw.		Open/Close		Act.-Posit. Sens.	-		X	1	1.5	8	57	(.000684)	
4.1.1.7	Igniter Oxid. Supply Vlv		Open/Close		Act.-Posit. Sens.	1.1.7		X	1	.6	8	57	(.000274)	
4.1.1.12	Main Fuel S/O Vlv		Open/Close		Act.-Posit. Sens.	1.1.7		X	1	11.0	8	.50	(.000044)	
-	Oxid. Flow Cont. Vlv		Not Feasible to Replace Without Engine Overhaul							-			-	
	Thrust Cont. Valve									-			-	
	Oxidizer Pump									-			-	
	Fuel Pump									-			-	
4.1.1.8	Fuel Pump Disch. Cool Down Vlv.		Open/Close		Act. Posit.	1.1.7		X	1	.5	5	.5	(.000013)	

C-50

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL 2 & 3F

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability: Parameter	% Risk	Method	Locat	Test	No. Test	No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
4.1.1.9	Fuel Pump Interstage Cool Down Vlv		Open/Close		Act. Posit. Sens.	1.1.7		X	1	.5	5	.5	(.000015)	
4.1.1.10	Oxid. Inlet S/O Valve		Open/Close		Act. Posit. Sens.	1.1.7		X	1	.6	5	.5	(.000015)	
4.1.1.11	Fuel Inlet S/O Valve		Open/Close		Act. Posit. Sens.	1.1.7		X	1	.6	5	.5	(.000015)	
4.1.1.15	Sensors/ Transducers					-		X	8				(.011172)	
4.1.1.15.1	Press		Read Press		Flt. only	-		X	4	6.0	8	57	(.009804)	
4.1.1.15.2	Temp		Read Temp		Flt. only	-		X	3	1.0	8	57	(.001368)	
4.1.1.15.3	Speed Transducer		Read RPM		Eng. Oper Only	-		X	1	5	5	.5	(.000012)	
4.1.1.13	Gimbal Assy		Crack		Visual	1.1.7		X	1	1	3	.5	(.000002)	
4.1.1.14	Interstage Bleed & P/R Vlv		Open/Close		Act. Posit. Sens.	1.1.7		X	1	11	5	.5	(.000028)	
4.1.1.16	Fuel Tank Press Valve		Open/Close		Act. Posit. Sens.	1.1.7		X	1	3	5	.5	(.000007)	
4.1.2	Gimbal Actuators (TVC)			0					2		8	1.0 .5	(.000924)	
4.1.2.1	Motor Actuators		Actuate Screw		Operate/Visual	1.1.7		X	(4)	10.89	8	1.0 .5	(.000522)	
4.1.2.2	Magnetic Clutch		Actuate Screw		Operate/Visual	1.1.7		X	(4)	2.4	8	1.0 .5	(.000114)	
4.1.2.3	Velocity Xducer		Measure Vel.		TM Feedback	1.1.7		X	(4)	.3	8	1.0 .5	(.000012)	

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL 2 & 3F

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability						No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
			Parameter	% Risk	Method	Locat	Test	No. Test						
4.1.2.4	Position Xducer		Measure Posit.		TM Feedback	1.1.7		X	(4)	.13	8	1.0 .5	(.000006)	
4.1.2.5	Servo Amplifier		Feedback Sign.		Operate	1.1.7		X	(4)	5.6	8	1.0 .5	(.000270)	
4.1.2.6	Ball Screw		Travel		Operate-Travel	1.1.7		X	(2)	.001	8	1.0 .5	-	
4.1.2.7	Bellows		Seal Unit.		Visual	1.1.7		X	(2)	.001	8	1.0 .5	-	
4.1.2.8	Case Valve		Relief Setting		Test Pressure	1.1.7		X	(2)	.001	8	1.0 .5	-	
4.2	Propulsion Support													
4.2.1	Propellant Feed			69.3	Verifiable					89.6	5		.011638	
4.2.1.1	LH_2 Feedline Ball Valve	No	Seal Fuel	23.1	Tank Leak Test	1.1.7	X		1	3.0	5	2 177	.002685	
4.2.1.2	LO_2 Feedline Ball Valve	No	Seal Oxidizer	23.1	Tank Leak Test	1.1.7	X		1	3.0	5	2 177	.002685	
4.2.1.3	1/2-in. Check Valve	Yes	Check Flow	15.4	Isol. C/V Test	1.1.7		X	1	2.0	5	2 177	.001790	
4.2.1.4	LH_2 Feedline Isol Monitor	Yes	Sense Valve Pos.	11.5	Valve Posit. Sens.	1.1.7	X		1	1.5	5	2 177	.001343	
4.2.1.5	Ball Valve Pneu Actuator	No	Open/Close	-	Act. Valve	1.1.7		X	1	0.4	5	0.5	.000001	
4.2.1.6														
4.2.1.7	LO_2 Feedline Isol. Monitor	Yes	Sense Valve Pos.	11.5	Valve Posit. Sensor	1.1.7	X		1	1.5	5	2 177	.001343	

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: 2 & 3F

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability						No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
			Parameter	% Risk	Method	Locat	Test	No. Test						
4.2.1.8	1/2-In. Check Valve	Yes	Check Flow	15.4	Isol. C/V Test	1.1.7		X	1	2.0	5	2 177	.001790	
4.2.1.9	Ball Valve Pneu. Actuat.	No	Open/Close	-	Act. Valve	1.1.7		X	1	0.4	5	0.5	.000001	
4.2.2	Vent (#1)			56.6					1		5		.048258	
4.2.2.1	Isolation Valves - LH_2	No	Leak to Vent	16.9	Test for Leaks	1.1.7		X	2/4	3.4	5	2 177	.012172	
4.2.2.2	Tug/Orbiter Ftg LH_2	Yes	Leak at Face	4.8	Halogen Test	2.3.9	X		1	1.96	5	2 177	.001754	
4.2.2.3	Vent & Relief Valves - LH_2	Yes	Open to Vent	28.3	Relief Setg.	1.1.7	X		2	5.7	5	2 177	.010203	
4.2.2.4	Isolation Valves LO_2	No	Leak to Vent	16.9	Test for Leaks	1.1.7		X	2/4	3.4	5	2 177	.012172	
4.2.2.5	Tug/Orbiter Ftg LO_2	Yes	Leak to Face	4.8	Halogen Test	2.3.9	X		1	1.96	5	2 177	.001754	
4.2.2.6	Vent & Relief Valve LO_2	Yes	Open to Vent	28.3	Relief Setg.	1.1.7	X		2	5.7	5	2 177	.010203	
4.2.3	Fill & Drain			100					1				.018351	
4.2.3.1	F&D Valve-LH_2	Yes	Open/Close Leak	34.5	Fill Cycle	2.4.3	X		3	3.4	5	2 177	.009129	
4.2.3.2	F&D Valve-LO_2	Yes	Open/Close Leak	34.5	Fill Cycle	2.4.3	X		3	3.4	5	2 177	.009129	
4.2.3.3	Disconnect LH_2	Yes	Seal to Orb.	10.3	Halogen Test	2.3.9	X		1	1.96	8	2	.000031	
4.2.3.4	Disconnect LO_2	Yes	Seal to Orb.	20.7	Halogen Test	2.3.9	X		2	1.96	8	2	.000062	
4.2.4	Pneumatic			100									.041140	
4.2.4.1	S/O Valve Modules	Part	Open/Close	100	Actuate Valves	1.1.7	X		22	2.0	5	10 177	(.041140)	

C-53

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: 2 & 3F

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability						No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
			Parameter	% Risk	Method	Locat	Test	No. Test						
4.2.5	Propellant Utilization			24.9					1				.012357	
4.2.5.1	LH_2 Capac. Probe	Yes	Quantity Meas.	12.1	Monitor Fill	2.4.3	X		1	1.0	8	10 177	.001496	
4.2.5.2	LO_2 Capac. Probe	Yes	Quantity Meas.	12.1	Monitor Fill	2.4.3	X		1	1.0	8	10 177	.001496	
4.2.5.3	Prop. Utiliz Assy	No	Control Flow	75.1	Calib.	1.1.7		X	1	6.2	8	10 177	.009275	
4.2.5.4	Capac. Probe Attach.	Yes	Seal Tank	-0.7	Hold Press.	1.1.7	X		2	.05	5	2 177	.000090	

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: 3F

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability: Parameter	% Risk	Method	Locat	Test	No. Test	No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
4.2.6	Pressurization Heated He + Eng. GH_2 Bleed			85.07	Testable					52.1			.066700	
4.2.6.1	He Tanks	Yes	Press. Volume	.14	Press in He		X		2	.05	5	10 177	(.000094)	
4.2.6.2	O_2-H_2 Burner	No	Burn Temp	.07	Temp Sensor	-		X	1	9.9	5	1	(.000050)	
4.2.6.3	LO_2 Supply Valve	No	Valve Open	2.65	Press at Burner			X	2	1.0	5	177	(.001770)	
4.2.6.4	LH_2 Supply Valve	No	Valve Open	2.65	Press at Burn	-		X	2	1.0	5	177	(.001770)	
4.2.6.5	Supply Orifices	No	Supply Flow	-	Flow at Burn			X	2	1.0	5	-	-	
4.2.6.6	Disconnect	Yes	Hold Press	2.80	Press in He		X		1	2.0	5	10 177	(.001870)	
4.2.6.7	He Solenoid Valve-LO_2	Yes	Valve Position	1.40	Press. in Tank		X		1	1.0	5	10 177	(.000935)	
4.2.6.8	He Solenoid Valves - LH_2	Yes	Valve Position	1.40	Press. in Tank		X		1	1.0	5	10 177	(.000935)	
4.2.6.9	He Check Valves	Yes	Check	.72				X	2	.27	5	177	(.000479)	
4.2.6.10	Plenums	Yes	Leak	.13	Hold Press		X		2	.05	5	177	(.000089)	
4.2.6.11	He Regulator	No	Press-Flow	3.32	Flowrate			X	1	2.5	5	177	(.002212)	
4.2.6.12	LO_2-LN_2 Press.-Orifices	Yes	Flow to Tank	-				X	2	-	5	177		
4.2.6.13	GN_2 Orifice	No	Flow Rate	-	Flow Rate	-		X	1	-	5	177	(.002212)	
4.2.6.14	GN_2 Sol-Valve	No	Valve Posit.	1.33	Valve Posit.	-		X	1	1.0	5	177	(.000885)	

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL 3F

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability: Parameter	% Risk	Method	Locat	Test	No. Test	No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NAKT	Attrib. Items R
4.2.6.15	GH_2 Check Val.	No	Shutoff	.36	Held He Press.		X		1	.27	5	177	(.000239)	
	GH_2 Check Val. Redund		Shutoff	.36	Leak Test			X	1	.27	5	177	(.000239)	
4.2.6.16	He Press Sensor	Yes	Tank Press.	13.3	Press in He 90		X		1	5.9	8	10 177	(.008826)	
4.2.6.17	He Temp Sensor	Yes	Tank Temp.	2.24	Temp in LH_2 90		X		1	1.0	8	10 177	(.001496)	
4.2.6.18	Burner Temp Sensor	No	Burner Temp	.01	Temp in Burner			X	1	1.0	8	1	(.000008)	
4.2.6.19	LH_2 Tank Press. Sensor	Yes	Preflt Press	25.40	TM Sensor		X		2	5.9	8	2 177	(.016897)	
4.2.6.20	LO_2 Tank Press Sensor	Yes	Preflt Press.	25.40	TM Sensor		X		2	5.9	8	2 177	(.016897)	
4.2.6.21	LO_2 LH_2 Tank Diffusers	Yes	Flow Rate	-				X	2	-	-	2 177	-	
4.2.6.22	LO_2 Abort Press. Valve	No	Valve Position	3.82	Posit. Sensors			X	2	3.4	2	10 177	(.002543)	
4.2.6.23	Vent & Relief Valve	Yes	No Leak	12.80	Tank Press		X		1	5.7	8	10 177	(.008527)	

C-56

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: TUG OPTION 3F

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability: Parameter	% Risk	Method	Locat	Test	No. Test	No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
4.3	ACPS Engine												.145797	
4.3.1	ACPS Module			0					4			48	.016589	
4.3.1.1	R-4D Axial Thruster	No	Flow Rate	3.7	Calib.	1.1.12		X	8	.16	10	48	.000614	
4.3.1.2	R-1E Tang'l Thruster	No	Flow Rate	3.7	Calib.	1.1.12		X	8	.16	10	48	(.000614)	
4.3.1.3	Thrustor Iso Vlv	No	Open/Close	46.3	Monitor	1.1.12		X	32	1.0	5	48	(.007680)	
4.3.1.4	Thrustor Chamb. Vlv	No	Open/Close	46.3	Monitor	1.1.12		X	32	1.0	5	48	(.007680)	
4.4	ACPS Support			91.2									.129208	
4.4.1	Tank (MMH)	Yes	Leak	13.9	Monitor Press	2.1.7	X		2	9.6	5	10 177	.017952	
4.4.2	Tank (N_2O_4)	Yes	Leak	13.9	Monitor Press	2.1.7	X		2	9.6	5	10 177	.017952	
4.4.2.1	Tank Bladders	Yes	Leak	-	Monitor Press	2.1.7	X		(2)	9.6		10 177	(.017952)	
4.4.3	Relief Vlv	Yes	Press Setg	11.1	Monitor Press	2.4.2	X		3	0.5		10 177	.001403	
4.4.3.1	Burst Disk	Yes	Press Setg		Monitor Press	2.4.2	X		(3)	0.1		10 177	(.000281)	
4.4.4	Grnd Quick Discon	Yes	Leak	2.8	Monitor Fill	2.4.2	X		2	1.96		10 177	.003665	
4.4.5	Fill/Drain & Disconn	Yes	Leak	1.5	Monitor Fill	2.4.2	X		2	1.0		10 177	.001870	
4.4.6	Module Iso Vlvs	Yes	Leak	5.8	Monitor Press	2.4.2	X		8	1.0		10 177	.007480	

PREFLIGHT VERIFICATION OF SUBSYSTEMS

MODEL: TUG OPTION 3F

Code No.	Functional Equipment Items	Funct Prior To Flt	Verification Capability						No. N	Fail/ 10^6 Hr λ	Stress Factor K	Use Time T	NλKT	Attrib. Items R
			Parameter	% Risk	Method	Locat	Test	No. Test						
4.4.7	Grnd Red He Vlvs	Yes	Leak	1.5	Monitor Press	2.4.2	X		2	1.0		10 177	.001870	
4.4.8	Fill/Drain S/O Vlv (He)	Yes	Open/Close	.7	Tank Press.	2.4.2	X		1	1.0	5	10 177	.000935	
4.4.9	Fill/Drain Check Vlv & QD	No	Check Flow	1.4	Syst Test	1.1.7		X	1	1.96	5	10 177	.001833	
4.4.10	He Press Cont Mod	Yes	Open/Close	12.6	Press at Tanks	1.1.7		X	1	(18.19)	5	177	(.016307)	
4.4.10.1	S/O Vlvs	Yes	Leak	2.9	Press at Tanks	1.1.7	X		(4)	1.0	5	10 177	.003740	
4.4.10.2	Press. Regs.	No	Cont. Press		Press at Tanks	1.1.7		X	(3)	2.5	5	177	.006637	
4.4.10.3	Switch (Press.)	No	Power		Press at Tanks	1.1.7		X	(6)	1.1	5	177	.005841	
4.4.10.4	Filter	No	Flow		Press at Tanks	1.1.7		X	(3)	.01	5	177	.000027	
4.4.10.5	ML Relay	No	Power Avail.		Press at Tanks	1.1.7		X	(1)	.05	5	177	.000044	
4.4.10.6	DRDT Switch	No	Power Avail.		Press at Tanks	1.1.7		X	(2)	.01	5	177	.000018	
4.4.11	Press. Sensors	Part.	Sense Press.	28.7	Monitor	2.4.2	X		5	7.92	5	10 177	.037026	
4.4.12	Temp. Sensors	Part	Sense Temp.	15.4	Monitor	2.1.7	X		7	3.03	5	10 177	.019831	
4.4.13	Module Inst. Connect	Yes	Proper Mod Cmds	3.0	Software	2.1.7	X		4	2.5	8	48	.003840	

Code 1.	Functional Equipment (Assembly, Component, Subassembly) Structure — 1.1.1.1: Subassembly Level 8, Component Level 7, Assembly Level 6	Number Per Tug	Level I Maintenance: Failures Per 100 Flts	Failures Per 5 Flts	Replace Comp/LRU	Repair Tug	Component Initial Stock	Component Float Stock (OPS)	Level II Maintenance: Subassy Failed/100 Flts	Subassy Failed/5 Flts	Replace Subassy	Repair Component	Subassy OPS Spares	Subassy Repair Kits-Depot	Repair Subassy at Depot
1.1	Fuel Tank	1											(Est Portion of NA)		
1.1.1	Access Gaskets	(5)	2.6	0.115	X								2	(0.005)	TA
1.1.2	Structure Repair Kit	(1)							1.3	0.065		X	1	(0.005)	
1.2	Oxidizer Tank	1													
1.2.1	Access Baskets	(5)	2.6	0.115	X								2	(0.005)	TA
1.2.2	Structure Repair Kit	(1)							1.3	0.065		X	1	(0.005)	
1.3	Body Structure														
1.3.1	Paint	(1)	3.9	0.180		X						X	1	(0.05)	
1.3.2	Cover Panels and Orbiter Kit Interface	(4)							2.6	0.130	X		1	(0.02)	
1.4	Thrust Structure	1													
1.4.1	Repair Kit	(1)							1.3	0.065		X	1	(0.03)	
1.5	Meteoroid Shield														
1.5.1	Repair Kit - AL on 3F GR Epoxy	1							6.5	0.325		X	2	(0.01)	
1.5.2	Repair Kit - Fiberglass	1							6.5	0.325		X	2	(0.01)	
1.6	Payload Docking														
1.6.1	Latches	4	0.4	0.02	X		0						1	0.3	X
1.6.2	Latch Trigger	4	0.4	0.02	X		0						1	0.3	X
1.6.3	Retract Cylinder	4	0.7	0.035	X		0						1	0.7	X
1.6.4	He Valves	2	0.2	0.009	X		0						1	0.2	X
1.6.5	Docking Ring Assembly	1	0.02	0.001	X		0						1	0.02	X
1.6.5.1	Frame Retract Motor	4	N/A Contingent Design				0				X				
1.6.5.2	Drive Mechanism	4					0				X				
1.6.5.3	Frame Tube Structure	1					0				X				
1.6.6	Energy Absorbers	8	0.72	0.036	X		0						1	0.50	X
1.6.7	Check Valves	8	0.001	-	X		0						1	0.003	TA
1.6.12	Hyd Accum	1	0.0126	0.006	X		0						1	0.08	X

Code - 1.1.1.1 → Subassembly Level 8; Component Level 7; Assembly Level 6

Code 1.0	Functional Equipment (Assembly, Component, Subassembly) Struc Structure (Cont)	Number Per Tug	Level I Maintenance: Failures Per 100 Flights	Level I Maintenance: Failures per 5 Flights	Level I Maintenance: Replace Comp/LRU	Level I Maintenance: Repair Tug	Level I Maintenance: Component Initial Stock	Level I Maintenance: Component Float Stock (OPS)	Level II Maintenance: Subassembly Failed/100 Flights	Level II Maintenance: Subassembly Failed/5 Flights	Level II Maintenance: Replace Subassembly	Level II Maintenance: Repair Component	Level II Maintenance: Subassembly OPS Spares	Level II Maintenance: Subassembly Repair Kits-Depot	Repair Subassembly at Depot
1.6.8	3-Position Gang Valve	1	0.28	0.014	X		0						1	0.16	X
1.6.8.1	Solenoid Actuators	2	0.002	-							X		0	0	TA
1.6.9	Vent/Release Valve	1	0.094	0.005	X		0						1	0.06	X
1.6.10	Pressure Tank	1	(In Pneumatics/Purge)				0						-		
1.6.11	Regulator	1	0.235	0.012	X		0						1	0.10	X
1.6.13	Spinup Drive Assembly	2	0.006	-	X		0						1	0.004	
1.6.14	Spinup Drive Idler	1	-	-	X		0						0	0	X
1.6.15	Pneumatic Actuator	3	0.006	-	X		0						1	0.001	X
1.6.16	Pneumatic Control Module	1	0.188	0.009	X		0						1	0.12	X
2.0	Thermal Control														
2.1	Insulation	-													
2.1.1	MLI Repair Kit	1	3.0	0.15		X	0					X	1	0.2	TA
2.2	Insulation Purge	-	11.20												
2.2.1	Liner Repair Kit	1	3.0	0.15		X	0					X	1	0.2	
2.2.2	Vent Valves	3	0.015	0.0008	X		0						1	0.008	X
2.2.3	Regulator	1	2.52	0.12	X		0						2	1.88	X
2.2.4	Pressure Controller	1	5.52	0.27	X		0						2	4.13	X
2.2.5	Valves-Solenoid	1	0.09	0.005	X		0						1	0.06	X
2.2.6	Relief Valve	1	0.05	0.002	X		0						1	0.04	X
2.2.7	He Bottle	1	0.005	-	X		0						0	0.003	X

Code	Code - 1.1.1.1 — Subassembly Level 8; Component Level 7; Assembly Level 6. Functional Equipment (Assembly, Component, Subassembly)	Number Per Tug	Level I Maintenance: Failures Per 100 Flts	Level I Maintenance: Failures Per 5 Flts	Level I Maintenance: Replace Comp/LRU	Level I Maintenance: Repair Tug	Level I Maintenance: Component Initial Stock	Level I Maintenance: Component Float Stock (OPS)	Level II Maintenance: Subassy Failed/100 Flts	Level II Maintenance: Subassy Failed/5 Flts	Level II Maintenance: Replace Subassy	Level II Maintenance: Repair Component	Level II Maintenance: Subassy OPS Spares	Level II Maintenance: Subassy Repair Kits-Depot	Repair Subassy at Depot
3.	Avionics														
3.1	Data Management		68.78												
3.1.1	Computer	2	15.1	0.75	X		2								
3.1.1.1	Central Processor	(2)							2.42	0.12	X		2	1.8	X
3.1.1.2	Memory Stack	(8)							12.11	0.61	X		3	9.2	X
3.1.1.3	Elect. Misc. (Box Repair)	(2)							0.61	0.03	X		1	0.45	X
3.1.2	Module Interface Unit														
3.1.2.1	BIV	10	4.84	0.24	X		1						2	3.5	X
3.1.2.2	PCU	24	11.63	0.58	X		2						3	8.2	X
3.1.2.3	DCU	20	9.69	0.48	X		1						3	7.5	X
3.1.2.4	RMU	20	9.69	0.48	X		1						3	7.5	X
3.1.2.5	DIV	2	0.97	0.048	X		1						1	0.7	X
3.1.2.6	SCU	6	2.91	0.14	X		1						2	2.2	X
3.1.3	DCU	2	4.84	0.24	X		1						2	3.5	X
3.1.5	Computer Interface Unit	1	0.61	0.03	X		0						1	0.45	X
3.1.6	Instrument Power Supplies	6	3.63	0.18	X		1						2	2.70	X

Code 3	Code - 1.1.1.1 ← Subassembly Level 8; Component Level 7; Assembly Level 6 Functional Equipment (Assembly, Component, Subassembly) Avionics	Number Per Tug	Level I Maintenance: Failures Per 100 Flts	Level I Maintenance: Failures Per 5 Flts	Level I Maintenance: Replace Comp/LRU	Level I Maintenance: Repair Tug	Level I Maintenance: Component Initial Stock	Level I Maintenance: Component Float Stock (OPS)	Level II Maintenance: Subassy Failed/ 100 Flts	Level II Maintenance: Subassy Failed/ 5 Flts	Level II Maintenance: Replace Subassy	Level II Maintenance: Repair Component	Level II Maintenance: Subassy OPS Spares	Level II Maintenance: Subassy Repair Kits-Depot	Repair Subassy at Depot
3.1.7	System Control Unit	3	4.84	0.24	X		1								
3.1.7.1	PC Board A	6							1.94	0.094	X		1	1.50	X
3.1.7.2	PC Board B	6							2.42	0.012	X		1	1.80	X
3.1.7.3	Box Misc	3							0.48	0.024			1	0.38	X
3.2	Guidance Navigation and Control														
3.2.1	IMU	2	50.40	2.52	X		4								
3.2.1.1	Gyros	6							28.80	1.44	X		5	20.0	X
3.2.1.2	Accelerometers	6							14.40	0.72	X		4	10.0	X
3.2.1.3	Sensor Electronics	2							2.88	0.14	X		2	1.80	X
3.2.1.4	Power Supply and Electronics	2							2.40	0.12	X		2	1.60	X
3.2.1.5	Housing Assembly and Coolant	2							1.92	0.10	X		2	1.20	X
3.2.2	Star Tracker	2	3.55	0.17	X		1								
3.2.2.1	Sensor	2							2.96	0.15	X		2	2.00	X
3.2.2.2	Stabilization Drive	2							0.59	0.03	X		1	0.45	X
3.2.3	TV Camera and Lights	-													
3.2.3.1	Laser Radar	1	0.80	0.040	X		0						1	0.60	X

Code - 1.1.1.1 ← Subassembly Level 8 / Component Level 7 / Assembly Level 6

Code	Functional Equipment (Assembly, Component, Subassembly)	Number Per Tug	Level I Maintenance						Level II Maintenance						Repair Subassy at Depot
3.	Avionics		Failures Per 100 Flts	Failures Per 5 Flts	Replace Comp/LRU	Repair Tug	Component Initial Stock	Component Float Stock (OPS)	Subassy Failed/ 100 Flts	Subassy Failed/ 5 Flts	Replace Subassy	Repair Component	Subassy Ops Spares	Subassy Repair Kits-Depot	
3.3	Communications														
3.3.1	OMNI Antenna	4	1.88	0.09	X		0						1	1.20	X
3.3.2	RF Multiplexer	1	0.52	0.026	X		0						1	C.40	X
3.3.3	Power Amplifier	1	6.39	0.32	X		1								
3.3.3.1	TWT	(4)							5.74	0.29	X		2	3.82	X
3.3.3.2	Circuitry	(1)							0.65	0.03	X		1	0.42	X
3.3.4	Transponder-Signals	1	1.22	0.06	X		0						1	0.15	X
3.3.4.1	PC Board	(2)							0.98	0.048			1	0.67	X
3.3.5	Command Decoder	1	1.30	0.065	X		0						1	0.90	X
3.3.6	Processor (Mod/Demod)	1	1.30	0.065	X		0						1		
3.3.6.1	PC Board	(2)							1.04	0.052	X		1	0.69	X
3.3.6.2	Circuitry	(1)							0.26	0.013	X		1	0.18	X
3.3.7	PCM Encoder	1	1.30	0.065	X		0						1	0.90	X
3.3.8	Tape Recorder	2	7.34	0.37	X		1	2							
3.3.8.1	Tape Drive Mechanics	2							1.47	0.07	X		1	1.00	X
3.3.8.2	Magnetic Heads	2							0.49	0.024	X		1	0.33	X
3.3.8.3	Electronics	2							5.39	0.269				3.60	X

Code 3.	Code - 1.1.1.1 — Subassembly Level 8, Component Level 7, Assembly Level 6 Functional Equipment (Assembly, Component, Subassembly) Avionics	Number Per Tag	Level I Maintenance: Failures Per 100 Flts	Failures Per 5 Flts	Replace Comp/LRU	Repair Tug	Component Initial Stock	Component Float Stock (OFS)	Level II Maintenance: Subassy Failed/ 100 Flts	Subassy Failed/ 5 Flts	Replace Subassy	Repair Component	Subassy OPS Spares	Subassy Repair Kits-Depot	Repair Subassy at Depot
3.3.9	Transmitter (Not Used in #2)														
3.3.1C	Comsec Equipment	1	1.22	0.06	X		0						1	0.86	X
3.3.11	Transponder (Standard)	1	1.22	0.06	X		0						1	0.20	X
3.3.11.1	PC Board	2							0.98	0.49	X			0.66	X
3.4	Instrumentation														
3.4.1	Sensors	1	16.85												
3.4.1.1	Strain	(10)	0.078	0.004		X	0						3	0.1	TA
3.4.1.2	Press Transducers	(25)	0.30	0.015	X		0						10	0.15	TA
3.4.1.3	Temperature Transducers	(30)	11.74	0.586	X		2						10	6.0	TA
3.4.1.4	Position Sensors	(20)	4.73	0.236	X		1						10	7.5	TA
3.4.2	Signal Conditioning	1													
3.4.2.1	Signal Conditioning Units	(65)	3.00	0.15			1						20	2.0	TA
3.4.3	Circuitry														

Code 3	Code - 1.1.1.1 ← Subassembly Level [illegible]; Component Level [illegible]; Assembly Level [illegible] Functional Equipment (Assembly, Component, Subassembly) Avionics	Number Per Tug	Level I Maintenance: Failures Per 100 Flts	Failures Per 5 Flts	Replace Comp/LRU	Repair Tug	Component Initial Stock	Component Float Stock (OPS)	Level II Maintenance: Subassy Failed/100 Flts	Subassy Failed/5 Flts	Replace Subassy	Repair Component	Subassy OPS Spares	Subassy Repair Kits-Depot	Repair Subassy at Depot
3.5	Elect Power														
3.5.1	Fuel Cell	2	2.66	0.13	X		1	2							
3.5.1.1	Fuel Cell PP	2							1.97	0.10	X		2	1.3	X
3.5.1.2	Reactant Control Valves	4							0.15	0.007	X		1	0.10	X
3.5.1.3	Coupled Regulators	4							0.37	0.019	X		1	0.25	X
3.5.1.4	Reactant Scrubbers	4							0.01	0.001	X		1	0.006	X
3.5.1.5	Vent Valves	4							0.15	0.007	X		1	0.10	X
3.5.2	Fuel Cell Reactants System														
3.5.2.1	O_2 Tank	1	0.005	-	X		0						1	0.003	X
3.5.2.2	H_2 Tank	1	0.005	-	X		0						1	0.003	X
3.5.2.3	O_2 Fill Valve	1	0.094	0.005	X		0						1	0.062	X
3.5.2.4	O_2 Vent/Relief Valve	1	0.41	0.020	X		0						1	0.26	X
3.5.2.5	H_2 Fill Valve	1	0.094	0.005	X		0						1	0.062	X
3.5.2.6	H_2 Vent/Relief Valve	1	0.41	0.020	X		0						1	0.26	X
3.5.2.7	O_2 Tank Pressure Gage	1	0.55	0.03	X		0						1	0.38	X
3.5.2.8	H_2 Tank Pressure Gage	1	0.55	0.03	X		0						1	0.38	X
3.5.3	Primary Battery	1	1.20	0.06	X		0	1						2.8	TA
3.6	Power Distribution		0.78												
3.6.1	Power Distribution Components	10	0.65	0.033	X		0						1	1.5	TA
3.6.2	Wire Harnesses (Kit)	10	0.13	0.006		X	0						1	0.25	TA

Code - 1.1.1.1 ← Subassembly Level 5; Component Level 7; Assembly Level 6

Code	Functional Equipment (Assembly, Component, Subassy)	Number Per Tug	Level I Maintenance: Failures Per 100 Flts	Level I Maintenance: Failures Per 5 Flts	Level I Maintenance: Replace Comp/LRU	Level I Maintenance: Repair Tug	Level I Maintenance: Component Initial Stock	Level I Maintenance: Component Float Stock (OPS)	Level II Maintenance: Subassy Failed/ 100 Flts	Level II Maintenance: Subassy Failed/ 5 Flts	Level II Maintenance: Replace Subassy	Level II Maintenance: Repair Component	Level II Maintenance: Subassy OPS Spares	Level II Maintenance: Subassy Repair Kits-Depot	Repair Subassy at Depot
4.1	Main Engine (Cont'd)														
4.1.2	Gimbal Actuators	2	0.09	0.005	X		0		0.053	0.003	X		1	0.3	
4.1.2.1	Motor Actuators	(4)							0.011	0.0005			1	0.015	X
4.1.2.2	Magnetic Clutch	(4)							0.001	--			0	0.01	TA
4.1.2.3	Velocity Transducer	(4)							0.001	--			0	0.01	TA
4.1.2.4	Position Transducer	(4)							0.027	0.001	X		0	0.04	
4.1.2.5	Servo Amplifier	(4)								--			1	0	X
4.1.2.6	Ball Screw	(2)								--			0	0.2	TA
4.1.2.7	Bellows	(2)								--			1	0.2	TA
4.1.2.8	Case Valve	(2)											0		
4.2	Main Engine Support														
4.2.1	Propellant Feed	1	0.46	0.023											
4.2.1.1	LH_2 Feedline Ball Valve	(1)	0.11	0.005	X		0						1	0.15	X
4.2.1.2	LO_2 Feedline Ball Valve	(1)	0.11	0.005	X		0						1	0.15	X
4.2.1.3	1/2-in. Check Valve	(2)	0.14	0.007	X		0						1	0.60	TA
4.2.1.4	Feedline Isolation Monitor	(2)	0.11	0.005	X		0						1	0.5	TA

Code 4.2	Code - 1.1.1.1 → Subassembly Level 8; Component Level 7; Assembly Level 6. Functional Equipment (Assembly, Component, Subassy) Main Engine Support	Number Per Tug	Level I Maintenance: Failures Per 100 Flts	Level I Maintenance: Failures Per 5 Flts	Level I Maintenance: Replace Comp/LRU	Level I Maintenance: Repair Tug	Level I Maintenance: Component Initial Stock	Level I Maintenance: Component Float Stock (OPS)	Level II Maintenance: Subassy Failed/100 Flts	Level II Maintenance: Subassy Failed 5 Flts	Level II Maintenance: Replace Subassy	Level II Maintenance: Repair Component	Level II Maintenance: Subassy OPS Spares	Level II Maintenance: Subassy Repair Kits-Depot	Repair Subassy at Depot
4.2.2	Vent	1	4.82	0.241											
4.2.2.1	Isolation Valves LH_2	(4)	1.22	0.061	X		0						1	0.816	
4.2.2.2	Tug Orbiter Fitting	(1)	0.18	0.009	X		0						1	0.120	
4.2.2.3	Vent and Relief Valves	(2)	1.02	0.051	X								1	0.682	X
4.2.2.4	Isolation Valves LO_2	(4)	1.22	0.061	X		0						1	0.816	
4.2.2.5	Tug/Orbiter FTG LO_2	(1)	0.18	0.009	X		0						1	0.120	
4.2.2.6	Vent and Relief Valves LO_2	(2)	1.02	0.051	X		0						1	0.682	X
4.2.3	Fill and Drain (and Abort)	1	1.83	0.092											
4.2.3.1	Valve LH_2	(3)	0.91	0.046	X		0						1	0.609	X
4.2.3.2	Valve LO_2	(3)	0.91	0.046	X		0						1	0.609	X
4.2.3.3	Disconnect LH_2	(1)	0.003	0.0002	X		0						1	0.002	X
4.2.3.4	Disconnect LO_2	(2)	0.006	0.0004	X		0						1	0.004	X
4.2.4	Pneumatic	1	4.11	0.206											
4.2.4.1	Control Valve Modules	22	(4.11)	(0.206)			0						2	2.75	X
4.2.5	Propellant Utilization	1	1.237	0.062											
4.2.5.1	LH_2 Capacity Probe	(1)	0.150	0.008	X		0							0.100	X
4.2.5.2	LO_2 Capacity Probe	(1)	0.150	0.008	X		0							0.100	X
4.2.5.3	Propellant Utilization Assembly	(1)	0.928	0.046	X		0							0.620	X
4.2.5.4	Capacity Probe Attach Gasket	(2)	0.009	0.0005	X		0							0.020	TA

Code - 1.1.1.1 ← Subassembly Level 8; Component Level 7; Assembly Level 6

Code 4	Functional Equipment (Assembly, Component, Subassembly) Propulsion	Number Per Tug	Level I Maintenance: Failures Per 100 Flts	Level I Maintenance: Failures Per 5 Flts	Level I Maintenance: Replace Comp/LRU	Level I Maintenance: Repair Tug	Level I Maintenance: Component Initial Stock	Level I Maintenance: Component Float Stock (OPS)	Level II Maintenance: Subassy Failed/ 100 Flts	Level II Maintenance: Subassy Failed/ 5 Flts	Level II Maintenance: Replace Subassy	Level II Maintenance: Repair Component	Level II Maintenance: Subassy OPS Spares	Level II Maintenance: Subassy Repair Kits-Depot	Repair Subassy at Depot
4.2.6	Pressurization														
4.2.6.1	He Tank	2	0.009	--	X		0						1	0.006	X
4.2.6.2	O_2H_2 Burner	1	0.005	--	X		0						1	0.003	X
4.2.6.3	LO_2 Supply Valve	2	0.178	0.008	X		0						1	0.125	X
4.2.6.4	LH_2 Supply Valve	2	0.178	0.008	X		0						1	0.125	X
4.2.6.5	Supply Orifices	2	---	--	X		0						0	--	TA
4.2.6.6	Disconnect	1	0.187	0.009	X		0						1	0.125	X
4.2.6.7	He Solenoid Valve-LO_2	1	0.094	0.005	X		0						1	0.060	X
4.2.6.8	He Solenoid Valve-LH_2	1	0.094	0.005	X		0						1	0.060	X
4.2.6.9	He Check Valves	2	0.048	0.002	X		0						1	0.125	TA
4.2.6.10	Plennums	2	0.009	--	X		0						1	0.023	TA
4.2.6.11	He Regulator	1	0.221	0.011	X		0						1	0.170	X
4.2.6.12	LO_2-LH_2 Pressure Orifices	2	---	--	X		0						0	--	TA
4.2.6.13	GH_2 Orifice	1	---	--	X		0						0	--	TA
4.2.6.14	GH_2 Solenoid Valve	1	0.089	0.004	X		0						1	0.058	X
4.2.6.15	GH_2 Check Valve	2	0.048	0.002	X		0						1	0.12	TA
4.2.6.16	He Pressure Sensor	1	0.88	0.044	X		0						1	2.0	TA
4.2.6.17	He Temperature Sensor	1	0.15	0.007	X		0						1	0.35	TA
4.2.6.18	Burner Temperature Sensor	1	---	--			0						1	--	TA
4.2.6.19	LH_2 Tank Pressure Sensor	2	1.69	0.08	X		0						1	3.9	TA
4.2.6.20	LO_2 Tank Pressure Sensor	2	1.69	0.08	X		0						1	3.9	TA
4.2.6.21	LO_2/LH_2 Tank Diffusers	2	---	--	X		0						0	--	TA
4.2.6.22	LO_2 Abort Pressure Valve	2	0.25	0.013	X		0						1	0.18	X
4.2.6.23	Vent/Relief Valve	1	0.85	0.043	X		0						1	0.60	X

Code - 1.1.1.1 ← Subassembly Level 8; Component Level 7; Assembly Level 6

Code	Functional Equipment (Assembly, Component, Subassy)	Number Per Tug	Level I Maintenance: Failures Per 100 Flts	Level I Maintenance: Failures Per 5 Flts	Level I Maintenance: Replace Comp/LRU	Level I Maintenance: Repair Tug	Level I Maintenance: Component Initial Stock	Level I Maintenance: Component Float Stock (OPS)	Level II Maintenance: Subassy Failed/100 Flts	Level II Maintenance: Subassy Failed/5 Flts	Level II Maintenance: Replace Subassy	Level II Maintenance: Repair Component	Level II Maintenance: Subassy OPS Spares	Level II Maintenance: Subassy Repair Kits-Depot	Repair Subassy at Depot
4.3	ACPS Engine														
4.3.1	ACPS Module	4	1.659	0.0830	X		0	1							
4.3.1.1	R-4D Axial Thrustor	8							0.061	0.0031	X		1	0.041	X
4.3.1.2	R-1E Tangential Thrustor	8							0.061	0.0031	X		1	0.041	X
4.3.1.3	Thruster Isolation Valve	32							0.768	0.0384	X		1	0.514	X
4.3.1.4	Thruster Chamber Valve	32							0.768	0.0384	X		1	0.514	X
4.4	ACPS Support														
4.4.1	Tank (MMH)	1	0.898	0.0449	X		0	1						0.601	X
4.4.2	Tank (N_2O_4)	1	0.898	0.0449	X		0	1						0.601	X
4.4.2.1	Tank Bladder	(2)							1.795	0.0898			1	2.043	TA
4.4.3	Relief Valve	3	0.140	0.0070	X		0	1						0.094	X
4.4.3.1	Burst Disk	(3)							0.028	0.0014			1	0.062	TA
4.4.4	Ground Check Disconnect	2	0.367	0.0184	X		0	1						0.246	X
4.4.5	Fill/Drain/Disconnect	2	0.187	0.0094	X		0	1						0.125	X
4.4.6	Module Isolation Valve	8	0.748	0.0374	X		0	1						0.500	X
4.4.7	Quad Redundant He Valve	2	0.187	0.0094	X		0	1						0.125	X
4.4.8	Fill/Drain Shutoff Valve (He)	1	0.094	0.0047	X		0	1						0.063	X
4.4.9	Fill/Drain Check Valve and Quick Disconnect	1	0.183	0.0092	X		0	1						0.122	X
4.4.10	He Pressure Control Module	1	1.702	0.0851	X		0	1						1.139	X
4.4.10.1	Shutoff Valve	(4)							0.374	0.0187	X		1	0.250	X
4.4.10.2	Pressure Regulator	(3)							0.701	0.0351	X		1	0.469	X
4.4.10.3	Switch (Pressure	(6)							0.617	0.0309	X		1	0.413	X

(Cont)

Code	Code - 1.1.1.1 (Subassembly Level 8; Component Level 7; Assembly Level 6) Functional Equipment (Assembly, Component, Subassy)	Number Per Tug	Level I Maintenance						Level II Maintenance						Repair Subassy at Depot
			Failures Per 100 Flts	Failures Per 5 Flts	Replace Comp/LRU	Repair Tug	Component Initial Stock	Component Float Stock (OPS)	Subassy Failed/ 100 Flts	Subassy Failed/ 5 Flts	Replace Component	Repair Component	Subassy OPS Spares	Subassy Repair Kits-Depot	
4.4.10.4	Filter	(3)							0.003	0.002	X		1	0.002	
4.4.10.5	ML Relay	(1)							0.005	0.003	X		1	0.003	
4.4.10.6	DPDT Switch	(2)							0.002	0.001	X		1	0.001	
4.4.11	Pressure Sensor	5	3.740	0.1870	X			2						8.340	TA
4.4.12	Temperature Sensor	7	1.983	0.0992	X			1						4.422	TA

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
IDENTIFICATION	CODE	NUMBER PER TUG	COMP SPARE COST ÷ COMP SHIPSET COST	COMP SPARE COST AS FRACTION OF ASSY COST	INITIAL SPARES - COMPONENTS	INITIAL COMP SPARES IN ESS*	AVG SUBASSY COST AS FRACTION OF ASSY COST	INITIAL SPARES - SUBASSYS	TOTAL INITIAL SPARES - SUBASSYS	INITIAL SUBASSY SPARES IN EES	TOTAL INITIAL SPARES IN EES	OPER SPARES - COMPONENTS	OPER COMP SPARES IN ESS	OPER SPARES - SUBASSYS	TOTAL OPER SPARES - SUBASSYS	OPER SUBASSY SPARES IN EES	TOTAL OPER SPARES IN EES	DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EES	TOTAL DEPOT SPARES IN EES
			R	Cj	SIj	R·Cj·SIj	FT Cj/Rh	SIi	ΣSIi	C1ΣSIi	EI	SOj	R·Cj·SOj	SOi	ΣSOi	C1ΣSOi	EO	SDi	ΣSDi	C1ΣSDi	ED
Structure	1.0										0						0.0647				0.3396
Fuel Tank	1.1	1	0.90	[0.064]											0.002		0.0001		0.010		0.0006
Access Gaskets	1.1.1	(5)												0.001				0.005			
Structure Repair Kits	1.1.2	(1)												0.001				0.005			
Oxidizer Tank	1.2	1	0.90	[0.048]											0.002		0.0001		0.010		0.0005
Access Gaskets	1.2.1	(5)												0.001				0.005			
Structure Repair Kits	1.2.2	(1)												0.001				0.005			
Body Structure	1.3	1	0.90	[0.471]											0.070		0.0330		0.070		0.0330
Paint	1.3.1	(1)												0.020				0.050			
Cover Panels, ER Kit	1.3.2	(4)												0.050				0.020			
Thrust Structure	1.4	1	0.90	[0.247]											0.100		0.0247		0.030		0.0074
Repair Kit	1.4 1	(1)												0.100				0.030			
Meteoroid Shield	1.5	1	0.90	[0.005]											0.300		0.0015		0.020		0.0001
Repair Kit-2 - GR Epoxy 3F - AL	1.5.1	(1)												0.160				0.010			
Repair Kit Fiberglass	1.5.2	(1)												0.140				0.010			

*ESS - EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

IDENTIFICATION	1 CODE	2 NUMBER PER TUG	3 COMP SPARE COST + COMP SHIPSET COST	4 COMP SPARE COST AS FRACTION OF ASSY COST	5 INITIAL SPARES - COMPONENTS	6 INITIAL COMP SPARES IN ESS*	7 AVG SUBASSY COST AS FRACTION OF ASSY COST	8 INITIAL SPARES - SUBASSYS	9 TOTAL INITIAL SPARES - SUBASSYS	10 INITIAL SUBASSY SPARES IN EES	11 TOTAL INITIAL SPARES IN EES	12 OPER SPARES - COMPONENTS	13 OPER COMP SPARES IN ESS	14 OPER SPARES - SUBASSYS	15 TOTAL OPER SPARES - SUBASSYS	16 OPER SUBASSY SPARES IN EES	17 TOTAL OPER SPARES IN EES	18 DEPOT REPAIR KITS IN EQUIV SUBASSYS	19 TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	20 TOTAL DEPOT REPAIR KITS IN EES	21 TOTAL DEPOT SPARES IN EES
			R	Ci	SIi	R·Ci·SIi	Ci/Ni	SIi	ΣSIi	C1ΣSIi	EI	SOi	R·Ci·SOi	SOi	ΣSOi	C1ΣSOi	EO	SDi	ΣSDi	C1ΣSDi	ED
Payload Docking	1.6	1	0.90	[0.165]							0		[0.0324]			0	[0.0053]			1.805	0.298
Latches	1.6.1	4	0.90	0.0146			0.0040					1	0.0036							0.30	
Latch Trigger	1.6.2	4		0.0146								1	0.0036							0.30	
Retract Cylinder	1.6.3	4		0.0146								1	0.0036							0.70	
Plumbing Kit	1.6.4	1		0.0037								1	0.0036							0.20	
Docking Ring Assy	1.6.5	1		0.0037								1	0.0036							0.07	
Frame Retract Motor	1.6.5.1	4	N/A - Contingent Design																		
Drive Mechanism	1.6.5.2	4																			
Frame Tube Structure	1.6.5.3	1																			
Energy Absorbers	1.6.6	8	0.90	0.0293								1	0.0036							0.12	
Check Valves	1.6.7	8		0.0293								1	0.0036							0.008	
3 Position Gang Valve	1.6.8	1		0.0037								1	0.0036							0.001	
Solenoid Actuators	1.6.8.1	2		0.0073								0								0	
Valves - Shut Off	1.6.9	1		0.0037								0								0	
Pressure Tank	1.6.10	1										0								0.003	
Regulator	1.6.11	1										1	0.0036							0.090	
Hydraulic Accumulator	1.6.12	1		0.0037								0								0.010	
Spin Up Drive Mech	1.6.13	2		0.0073								0								0	
Spin Up Drive Motors	1.6.14	2		0.0073								0								0.003	

*ESS - EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

Option 2 and 3F

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
IDENTIFICATION	CODE	NUMBER PER TUG	COMP SPARE COST ÷ COMP SHIPSET COST	COMP SPARE COST AS FRACTION OF ASSY COST	INITIAL SPARES - COMPONENTS	INITIAL COMP SPARES IN ESS*	AVG SUBASSY COST AS FRACTION OF ASSY COST	INITIAL SPARES - SUBASSYS	TOTAL INITIAL SPARES - SUBASSYS	INITIAL SUBASSY SPARES IN EES	TOTAL INITIAL SPARES IN EES	OPER SPARES - COMPONENTS	OPER COMP SPARES IN ESS	OPER SPARES - SUBASSYS	TOTAL OPER SPARES - SUBASSYS	OPER SUBASSY SPARES IN EES	TOTAL OPER SPARES IN EES	DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EES	TOTAL DEPOT SPARES IN EES
			R	Cj	Sij	R·Cj·Sij	Ci/Ni	Si	ΣSi	C1ΣSi	EI	SOj	R·Cj·SOj	SOi	ΣSOi	C1ΣSOi	EO	SDi	ΣSDi	C1ΣSDi	ED
Thermal Control	2.0										0						0.495				0.781
Insulation	2.1		0.9	[0.21]																0.20	0.042
MLI Repair Kit	2.1.1	1												(1)		0.238	0.05		0.20		
Insulation Purge	2.2		0.9	[C.79]			0.088									0.50	0.395				0.739
Liner Repair Kit	2.2.1	1												(1)		0.05	0.05			0.200	
Vent Valves	2.2.2	3												(1)		0.15		0.008	6.121	0.539	
Regulator	2.2.3	1												(2)		0.10		1.88			
Pressure Controller	2.2.4	1												(2)		0.10		4.13			
Valves - Solenoid	2.2.5	1												(1)		0.05		0.06			
Relief Valve	2.2.6	1												(1)		0.05		0.04			
He Bottle	2.2.7	1												0				0.003			

*ESS - EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

IDENTIFICATION	1 CODE	2 NUMBER PER TUG	3 COMP SPARE COST ÷ COMP SHIPSET COST R	4 COMP SPARE COST AS FRACTION OF ASSY COST C_j	5 INITIAL SPARES - COMPONENTS SI_j	6 INITIAL COMP SPARES IN ESS* $R \cdot C_j \cdot SI_j$	7 AVG SUBASSY COST AS FRACTION OF ASSY COST C_i/N_i	8 INITIAL SPARES - SUBASSYS SI_i	9 TOTAL INITIAL SPARES - SUBASSYS ΣSI_i	10 INITIAL SUBASSY SPARES IN EES $C_1 \Sigma SI_i$	11 TOTAL INITIAL SPARES IN EES EI	12 OPER SPARES - COMPONENTS SO_j	13 OPER COMP SPARES IN ESS $R \cdot C_j \cdot SO_j$	14 OPER SPARES - SUBASSYS SO_i	15 TOTAL OPER SPARES - SUBASSYS ΣSO_i	16 OPER SUBASSY SPARES IN EES $C_1 \Sigma SO_i$	17 TOTAL OPER SPARES IN EES EO	18 DEPOT REPAIR KITS IN EQUIV SUBASSYS SD_i	19 TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS ΣSD_i	20 TOTAL DEPOT REPAIR KITS IN EES $C_1 \Sigma SD_i$	21 TOTAL DEPOT SPARES IN EES ED
Avionics	3.0										0.361						1.359				0.728
Data Management	3.1			[0.264]		[0.330]				[0.356] [0.026]						[0.417]				[0.714]	
Computer	3.1.1	2	0.45	0.25	2	0.225	0.021								6	0.126			11.45	0.240	
Central Processor	3.1.1.1	(2)												2				1.8			
Memory Stack	3.1 1.2	(8)												3				9.2			
Electronic Misc (Box P)	3.1.1.3	(2)												1				0.45			
Mod I/F Unit	3.1.2			0.30			0.0037		7	0.026					14	0.051			29.6	0.108	
BIU	3.1.2.1	10						1						2				3.5			
PCU	3.1.2.2	24						2						3				8.2			
DCU	3.1.2.3	20						1						3				7.5			
RMU	3.1.2.4	20						1						3				7.5			
DIU	3.1.2.5	2						1						1				0.7			
SCU	3.1.2.6	6						1						2				2.2			
DCU	3.1.3	2	0.45	0.10	1	0.045								2	2	0.090		3.5		0.158	
(No 3.1.4)																					
Computer I/F Unit	3.1.5	1	0.90	0.10	0									1	1	0.090		0.45	0.045	0.041	
Inst Power Supply	3.1.6	6	0.15	0.10	1	0.015								2		0.030		2.70		0.0005	
System Control Unit	3.1.7	3	0.30	0.15	1	0.045	0.010								3	0.030			3.68	0.166	
PC Board A	3.1.7.1	(6)												1				1.50			
PC Board B	3.1.7.2	(6)												1				1.80			
Box Misc	3.1.7.3	(3)												1				0.38			

*ESS - EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
IDENTIFICATION	CODE	NUMBER PER TUG	COMP SPARE COST ÷ COMP SHIPSET COST	COMP SPARE COST AS FRACTION OF ASSY COST	INITIAL SPARES - COMPONENTS	INITIAL COMP SPARES IN ESS*	AVG SUBASSY COST AS FRACTION OF ASSY COST	INITIAL SPARES SUBASSYS	TOTAL INITIAL SPARES - SUBASSYS	INITIAL SUBASSY SPARES IN EES	TOTAL INITIAL SPARES IN EES	OPER SPARES - COMPONENTS	OPER COMP SPARES IN ESS	OPER SPARES - SUBASSYS	TOTAL OPER SPARES - SUBASSYS	OPER SUBASSY SPARES IN EES	TOTAL OPER SPARES IN EES	DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EES	TOTAL DEPOT SPARES IN EES
			R	C_I	SI_I	$R \cdot C_I \cdot SI_I$	C_I/N_I	SI_I	ΣSI_I	$C1\Sigma SI_I$	EI	SO_I	$R \cdot C_I \cdot SO_I$	SO_I	ΣSO_I	$C1\Sigma SO_I$	EO	SD_I	ΣSD_I	$C1\Sigma SD_I$	ED
G, N & C	3.2			[0.182]		[1.013]				0						[0.718]				[1.182]	
IMU	3.2.1	2	0.45	0.50	4	0.900	0.0278								15	0.417			34.6	0.961	
Gyros	3.2.1.1	6												5				20.0			
Accelerometers	3.2.1.2	6												4				10.0			
Sensor Electronics	3.2.1.3	2												2				1.8			
Power Supply & Electronics	3.2.1.4	2												2				1.6			
Housing Assy & Coolant	3.2.1.5	2												2				1.2			
Star Tracker	3.2.2	2	0.45	0.25	1	0.113	0.0625								3	0.188			2.45	0.153	
Sensor	3.2.2.1	2												2				2.00			
Stabilizer Drive	3.2.2.2	2												1				0.45			
TV Camera & Lights	3.2.3		0.45	0.25	0										1	0.113			0.60	0.068	
Laser Radar	3.2.3.1	1			0									1				0.60			

*ESS - EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

Option 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
IDENTIFICATION	CODE	NUMBER PER TUG	COMP SPARE COST ÷ COMP SHIPSET COST	COMP SPARE COST AS FRACTION OF ASSY COST	INITIAL SPARES - COMPONENTS	INITIAL COMP SPARES IN ESS*	AVG SUBASSY COST AS FRACTION OF ASSY COST	INITIAL SPARES - SUBASSYS	TOTAL INITIAL SPARES - SUBASSYS	INITIAL SUBASSY SPARES IN EES	TOTAL INITIAL SPARES IN EES	OPER SPARES - COMPONENTS	OPER COMP SPARES IN ESS	OPER SPARES - SUBASSYS	TOTAL OPER SPARES - SUBASSYS	OPER SUBASSY SPARES IN EES	TOTAL OPER SPARES IN EES	DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EES	TOTAL DEPOT SPARES IN EES
			R	C_j	SI_j	$R \cdot C_j \cdot SI_j$	C_i/N_i	SI_i	ΣSI_i	$C_1 \Sigma SI_i$	EI	SO_j	$R \cdot C_j \cdot SO_j$	SO_i	ΣSO_i	$C_1 \Sigma SO_i$	EO	SD_i	ΣSD_i	$C_1 \Sigma SD_i$	ED
Communications	3.3			[0.349]		[0.132]				0			[2.609]			[2.881]				[0.684]	
Omni Antenna	3.3.1	4	0.225	0.035	0							1	0.008			0.272		1.20		0.009	
RF Multiplexer	3.3.2	1	0.90	0.077	0							1	0.693					0.40		0.069	
Power Amplifier	3.3.3	1	0.90	0.077	1	0.069	0.0154								3	0.046			4.24	0.065	
TWT	3.3.3.1	(4)												2				3.82			
Circuitry	3.3.3.2	(1)												1				0.42			
Transponder - SGLS	3.3.4	(1)	0.90	0.077	0							1	0.693					0.15		0.104	
PC Board	3.3.4.1	(2)					0.0385							1		0.039		0.67		0.026	
Command Decoder	3.3.5	1	0.90	0.077	0							1	0.693					0.90			
Processor (Mod/Demod)	3.3.6	1	0.90	0.140	0		0.0467					1	0.126		3	0.140			0.87	0.041	
PC Board	3.3.6.1	(2)												1				0.69			
Circuitry	3.3.6.2	(1)												1				0.18			
PCM Encoder	3.3.7	1	0.90	0.077	0									1				0.90		0.62	
Tape Recorder	3.3.8	2	0.45	0.140	1	0.063	0.0233					2	0.126		2	0.047			4.93	0.115	
Tape Drive Mech	3.3.8.1	2												1				1.00			
Magnetic Heads	3.3.8.2	2												1				0.33			
Electronics	3.3.8.3	2																3.60			

*EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

Option 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
IDENTIFICATION	CODE	NUMBER PER TUG	COMP SPARE COST ÷ COMP SHIPSET COST	COMP SPARE COST AS FRACTION OF ASSY COST	INITIAL SPARES – COMPONENTS	INITIAL COMP SPARES IN ESS*	AVG SUBASSY COST AS FRACTION OF ASSY COST	INITIAL SPARES – SUBASSYS	TOTAL INITIAL SPARES – SUBASSYS	INITIAL SUBASSY SPARES IN EES	TOTAL INITIAL SPARES IN EES	OPER SPARES – COMPONENTS	OPER COMP SPARES IN EES	OPER SPARES – SUBASSYS	TOTAL OPER SPARES – SUBASSYS	OPER SUBASSY SPARES IN EES	TOTAL OPER SPARES IN EES	DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EES	TOTAL DEPOT SPARES IN EES
			R	C_i	SI_j	$R \cdot C_j \cdot SI_j$	A_T C_j/N_k	SI_i	ΣSI_i	$C1\Sigma SI_i$	EI	SO_j	$R \cdot C_j \cdot SO_j$	SO_i	ΣSO_i	$C1\Sigma SO_i$	EO	SD_i	ΣSD_i	$C1\Sigma SD_i$	ED
	3.3.9 Not Used									0											
Comsec Equipment	3.3.10	1	0.90	0.150		0					0	1	0.135					0.86		0.116	
Transponder	3.3.11	1	0.90	0.150		0	0.0750				0	1	0.135					0.20		0.027	
PC Board	3.3.11.1	2																0.66		0.050	

*ESS – EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
IDENTIFICATION	CODE	NUMBER PER TUG	COMP SPARE COST ÷ COMP SHIPSET COST	COMP SPARE COST AS FRACTION OF ASSY COST	INITIAL SPARES - COMPONENTS	INITIAL COMP SPARES IN ESS*	AVG SUBASSY COST AS FRACTION OF ASSY COST	INITIAL SPARES - SUBASSYS	TOTAL INITIAL SPARES - SUBASSYS	INITIAL SUBASSY SPARES IN EES	TOTAL INITIAL SPARES IN EES	OPER SPARES - COMPONENTS	OPER COMP SPARES IN ESS	OPER SPARES - SUBASSYS	TOTAL OPER SPARES - SUBASSYS	OPER SUBASSY SPARES IN EES	TOTAL OPER SPARES IN EES	DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EES	TOTAL DEPOT SPARES IN EES
			R	C_j	S_{ij}	$R \cdot C_j \cdot S_{ij}$	C_1/N_1	S_{I_1}	ΣS_{I_1}	$C_1 \Sigma S_{I_1}$	EI	SO_j	$R \cdot C_j \cdot SO_j$	SO_1	ΣSO_1	$C_1 \Sigma SO_1$	EO	SD_1	ΣSD_1	$C_1 \Sigma SD_1$	ED
Electrical Power	3.4			[0.192]		[0.180]				0						[0.583]				[0.442]	
Fuel Cells	3.4.1	2	0.45	0.40	1	0.180	0.0222					2	0.360		6	0.133			1.756	0.039	
Fuel Cell PP	3.4.1.1	2												2				1.3			
Reactant Control Valve	3.4.1.2	4												1				0.10			
Coupled Regulator	3.4.1.3	4												1				0.25			
Reactant Scrubbers	3.4.1.4	4												1				0.006			
Vent Valves	3.4.1.5	4												1				0.10			
FC Reactant System	3.4.2		0.9	0.45	0		0.056								8	0.450			1.410	0.025	
O_2 Tank	3.4.2.1	1												1				0.003			
H_2 Tank	3.4.2.2	1												1				0.003			
O_2 Fill Valve	3.4.2.3	1												1				0.062			
O_2 Vent/Relief Valve	3.4.2.4	1												1				0.260			
H_2 Fill Valve	3.4.2.5	1												1				0.062			
H_2 Vent/Relief Valve	3.4.2.6	1												1				0.260			
O_2 Tank Pressure Gage	3.4.2.7	1												1				0.380			
H_2 Tank Pressure Gage	3.4.2.8	1												1				0.380			
Primary Battery	3.4.3	1	0.9	0.15	0							1	0.135					2.8	2.8	0.378	
Power Distribution	3.5		0.9	[0.007]	0		0.050								2	0.100			1.75	[0.088]	
Power Distribution Components	3.5.1	10												1				1.5			
Wire Harnesses Kit	3.5.2	10												1				0.25			

* EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

Option 3F

IDENTIFICATION	1 CODE	2 NUMBER PER TUG	3 COMP SPARE COST : COMP SHIPSET COST	4 COMP SPARE COST AS FRACTION OF ASSY COST	5 INITIAL SPARES - COMPONENTS	6 INITIAL COMP SPARES IN ESS*	7 AVG SUBASSY COST AS FRACTION OF ASSY COST	8 INITIAL SPARES - SUBASSYS	9 TOTAL INITIAL SPARES - SUBASSYS	10 INITIAL SUBASSY SPARES IN EES	11 TOTAL INITIAL SPARES IN EES	12 OPER SPARES - COMPONENTS	13 OPER COMP SPARES IN EES	14 OPER SPARES - SUBASSYS	15 TOTAL OPER SPARES - SUBASSYS	16 OPER SUBASSY SPARES IN EES	17 TOTAL OPER SPARES IN EES	18 DEPOT REPAIR KITS IN EQUIV SUBASSYS	19 TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	20 TOTAL DEPOT REPAIR KITS IN EES	21 TOTAL DEPOT SPARES IN EES
			R	Ci	SNi	R-Ci-SNi	Ci/Ni	Si	ΣSi	C1ΣSi	EI	SOj	R-Cj-SOj	SOi	ΣSOi	C1ΣSOi	EO	SDi	ΣSDi	C1ΣSDi	ED
Propulsion	4.0									0.861	0.183					0.138				0.034	Note 1
Main Engine	4.1			[0.213]		0.855				0	0.855						(0.647)				(0.158)
Engine	4.1.1	1	0.90	0.95	1	0.855	0.0413				0.162				15	0.620	0.123		2.96	0.122	
Igniter	4.1.1.1	1												1				0.1			
Igniter Excite-	4.1.1.2	1												1				0.1			
Prestart Solenoid Valve	4.1.1.3	1												1				0.8			
Prestart He Pressure Switch	4.1.1.4	1												1				0.5			
Start Solenoid Valve	4.1.1.5	1												1				0.8			
Start He Pressure Switch	4.1.1.6	1												1				0.1			
Igniter Oxid Supply Valve	4.1.1.7	1												1				0.1			
Fuel Pump Disch Cool Down Valve	4.1.1.8	1												1				0.05			
F.P. Interstage Cool Down Valve	4.1.1.9	1												1				0.05			
Oxidizer Inlet S/O Valve	4.1.1.10	1												1				0.05			
Fuel Inlet S/O Valve	4.1.1.11	1												1				0.05			
Main Fuel S/O Valve	4.1.1.12	1												1				0.05			
Gimbal Assy	4.1.1.13	1												1				0.01			
Interstage Bleed & PR Valve	4.1.1.14	1												1				0.01			
Sensors/Transducers	4.1.1.15	8						(0.0052)							(4)	0.21			(6.6)	0.034	
Pressure	4.1.1.15.1	(4)												2				4.5			
Temperature	4.1.1.15.2	(3)												1				1.0			
Speed	4.1.1.15.3	(1)												1				0.1			
Fuel Tank Pressure Valve	4.1.1.16	1												1				0.1			
4.1.1.17 - 4.1.1.21 No Maintenance Possible																					

Note 1 Main Engine Omitted for Depot.

*ESS - EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

C-79

IDENTIFICATION	1 CODE	2 NUMBER PER TUG	3 COMP SPARE COST : COMP SHIPSET COST	4 COMP SPARE COST AS FRACTION OF ASSY COST	5 INITIAL SPARES - COMPONENTS	6 INITIAL COMP SPARES IN ESS*	7 AVG SUBASSY COST AS FRACTION OF ASSY COST	8 INITIAL SPARES - SUBASSYS	9 TOTAL INITIAL SPARES - SUBASSYS	10 INITIAL SUBASSY SPARES IN EES	11 TOTAL INITIAL SPARES IN EES	12 OPER SPARES - COMPONENTS	13 OPER COMP SPARES IN ESS	14 OPER SPARES - SUBASSYS	15 TOTAL OPER SPARES - SUBASSYS	16 OPER SUBASSY SPARES IN EES	17 TOTAL OPER SPARES IN EES	18 DEPOT REPAIR KITS IN EQUIV SUBASSYS	19 TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	20 TOTAL DEPOT REPAIR KITS IN EES	21 TOTAL DEPOT SPARES IN EES
			R	C_I	SI_J	$R \cdot C_I \cdot SI_J$	C_I/N_I	SI_I	ΣSI_I	$C1 \Sigma SI_I$	EI	SO_J	$R \cdot C_I \cdot SO_J$	SO_I	ΣSO_I	$C1 \Sigma SO_I$	EO	SD_I	ΣSD_I	$C1 \Sigma SD_I$	ED
Gimbal Actuators	4.1.2	2	0.45	0.05	0						0	1	0.023								
Motor Actuators	4.1.2.1	(4)					0.0019							1	3	0.0058		0.3	0.91	0.0018	
Magnetic Clutch	4.1.2.2	(4)												0				0.15			
Velocity Transducer	4.1.2.3	(4)												0				0.01			
Position Transducer	4.1.2.4	(4)												0				0.01			
Servo Amplifier	4.1.2.5	(4)												1				0.04			
Ball Screw	4.1.2.6	(2)												0				0			
Bellows	4.1.2.7	(2)												1				0.2			
Case Valve	4.1.2.8	(2)												0				0.2			

*EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

IDENTIFICATION	1 CODE	2 NUMBER PER TUG	3 COMP SPARE COST ÷ COMP SHIPSET COST	4 COMP SPARE COST AS FRACTION OF ASSY COST	5 INITIAL SPARES – COMPONENTS	6 INITIAL COMP SPARES IN ESS*	7 AVG SUBASSY COST AS FRACTION OF ASSY COST	8 INITIAL SPARES – SUBASSYS	9 TOTAL INITIAL SPARES – SUBASSYS	10 INITIAL SUBASSY SPARES IN EES	11 TOTAL INITIAL SPARES IN EES	12 OPER SPARES – COMPONENTS	13 OPER COMP SPARES IN ESS	14 OPER SPARES – SUBASSYS	15 TOTAL OPER SPARES – SUBASSYS	16 OPER SUBASSY SPARES IN EES	17 TOTAL OPER SPARES IN EES	18 DEPOT REPAIR KITS IN EQUIV SUBASSYS	19 TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	20 TOTAL DEPOT REPAIR KITS IN EES	21 TOTAL DEPOT SPARES IN EES
			R	C_j	S_{ij}	$R \cdot C_j \cdot S_{ij}$	C_j/N_i	S_i	ΣS_i	$C1\Sigma S_i$	EI	SO_j	$R \cdot C_j \cdot SO_j$	SO_i	ΣSO_i	$C1\Sigma SO_i$	EO	SO_i	ΣSO_i	$C1\Sigma SO_i$	EO
Main Engine Support	4.2			[0.447]		0				0	0					0.372	0.163			0.141	0.062
Propellant Feed	4.2.1	1	0.90	0.20		0	0.033								4	0.132			1.762	0.058	
LH_2 Feed Line Ball Valve	4.2 1.1	(1)			0									1				0.181			
LO_2 Feed Line Ball Valve	4.2 1.2	(1)			0			0						1				0.181			
1/2 In. Check Valve	4.2.1.3	(2)			0			0						1				0.080	TA		
Feedline Isolation Monitor	4.2 1.4	(2)			0			0						1				0.060	TA		
Vent	4.2 2	1	0.90	0.10		0	0.007								6	0.042			3.24	0.023	
LH_2 Isolation Valves	4.2.2.1	(4)			0			0						1				0.816			
Tug-Orbiter Fitting LH_2	4.2.2.2	(1)			0			0						1				0.120			
Vent & Relief Valves	4.2.2.3	(2)			0			0						1				0.682			
LO_2 Isolation Valves	4.2.2.4	(4)			0			0						1				0.816			
T-O Fitting LO_2	4.2.2.5	(1)			0			0						1				0.120			
V & R Valves LO_2	4.2.2.6	(2)			0			0						1				0.682			
Fill, Drain, Abort	4.2.3	1	0.90	0.15		0	0.017								4	0.068			1.22	0.021	
LH_2 Valve	4.2.3.1	(3)			0			0						1				0.609			
LO_2 Valve	4.2.3.2	(3)			0			0						1				0.609			
LH_2 Disconnect	4.2.3.3	(1)			0			0						1				0.002			
LO_2 Disconnect	4.2.3.4	(2)			0			0						1				0.004			
Pneumatic	4.2.4	1	0.90	0.10		0	0.005								2	0.010			2.75	0.014	
Control Valve Mods (See Insul. Purge for Other Hdwe.)	4.2.4.1	22			0			0						2				2.75			

*ESS - EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

IDENTIFICATION	1 CODE	2 NUMBER PER TUG	3 COMP SPARE COST ÷ COMP SHIPSET COST	4 COMP SPARE COST AS FRACTION OF ASSY COST	5 INITIAL SPARES – COMPONENTS	6 INITIAL COMP SPARES IN ESS*	7 AVG SUBASSY COST AS FRACTION OF ASSY COST	8 INITIAL SPARES – SUBASSYS	9 TOTAL INITIAL SPARES – SUBASSYS	10 INITIAL SUBASSY SPARES IN EES	11 TOTAL INITIAL SPARES IN EES	12 OPER SPARES – COMPONENTS	13 OPER COMP SPARES IN ESS	14 OPER SPARES – SUBASSYS	15 TOTAL OPER SPARES – SUBASSYS	16 OPER SUBASSY SPARES IN EES	17 TOTAL OPER SPARES IN EES	18 DEPOT REPAIR KITS IN EQUIV SUBASSYS	19 TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	20 TOTAL DEPOT REPAIR KITS IN EES	21 TOTAL DEPOT SPARES IN EES
			R	C_j	SI_j	$R \cdot C_j \cdot SI_j$	C_i/N_i	SI_i	ΣSI_i	$C1 \Sigma SI_i$	EI	SO_j	$R \cdot C_j \cdot SO_j$	SO_i	ΣSO_i	$C1 \Sigma SO_i$	EO	SD_i	ΣSD_i	$C1 \Sigma SD_i$	ED
	4.2 (Cont'd)																				
Propellant Utilization	4.2.5	1	0.90	0.15			0.030								4	0.120			0.840	0.025	
LH_2 Capacitor Probe	4.2.5.1	(1)			0			0						1				0.100			
LO_2 Capacitor Probe	4.2.5.2	(1)			0			0						1				0.100			
Propellant Utilization Assy	4.2.5.3	(1)			0			0						1				0.620			
Capacitor Probe Attach/ Gaskets	4.2.5.4	(2)			0			0						1				0.020	(TA)		

* EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

IDENTIFICATION	1 CODE	2 NUMBER PER TUG	3 COMP SPARE COST ÷ COMP SHIPSET COST	4 COMP SPARE COST AS FRACTION OF ASSY COST	5 INITIAL SPARES - COMPONENTS	6 INITIAL COMP SPARES IN ESS*	7 AVG SUBASSY COST AS FRACTION OF ASSY COST	8 INITIAL SPARES - SUBASSYS	9 TOTAL INITIAL SPARES - SUBASSYS	10 INITIAL SUBASSY SPARES IN EES	11 TOTAL INITIAL SPARES IN EES	12 OPER SPARES - COMPONENTS	13 OPER COMP SPARES IN ESS	14 OPER SPARES - SUBASSYS	15 TOTAL OPER SPARES - SUBASSYS	16 OPER SUBASSY SPARES IN EES	17 TOTAL OPER SPARES IN EES	18 DEPOT REPAIR KITS IN EQUIV SUBASSYS	19 TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	20 TOTAL DEPOT REPAIR KITS IN EES	21 TOTAL DEPOT SPARES IN EES
			R	C_j	S_{ij}	$R \cdot C_j \cdot S_{ij}$	$\frac{\Sigma C_i}{N_i}$	S_i	ΣS_i	$C_1 \Sigma S_i$	EI	SO_j	$R \cdot C_j \cdot SO_j$	SO_i	ΣSO_i	$C_1 \Sigma SO_i$	EO	SD_i	ΣSD_i	$C_1 \Sigma SD_i$	ED
Pressurization	4.2.6			0.30			0.0086				0				19	0.163			11.93	0.102	
He Tank	4.2.6.1	2												1				0.006			
O_2H_2 Burner	4.2.6.2	1												1				0.003			
LO_2 Supply Valve	4.2 6.3	2												1				0.125			
LH_2 Supply Valve	4.2.6.4	2												1				0.125			
Supply Orifice	4.2 6.5	2												0					(TA)		
Disconnect	4.2.6.6	1												1				0.125			
He Solenoid Valve - LO_2	4.2.6.7	1												1				0.060			
He Solenoid Valve - LH_2	4.2.6.8	1												1				0.060			
He Check Valve	4.2.6.9	2												1				0.125	(TA)		
Plenum	4.2.6.10	2												1				0.023	(TA)		
He Regulator	4.2.6.11	1												1				0.170			
LO_2-LH_2 Pres. Orif.	4.2.6.12	2												0					TA		
GH_2 Orifice	4.2.6.13	1												0					TA		
GH_2 Solenoid Valve	4.2.6.14	1												1				0.058			
He Check Valve	4.2.6.15	2												1				0.120	TA		
He Press. Sensor	4.2.6.16	1												1				2.000	TA		
He Temp. Sensor	4.2.6.17	1												1				0.350	TA		
Burner Temp. Sensor	4.2.6.18	1												1					TA		
LH_2 Tank Press Sensor	4.2.6.19	2												1				3.900	TA		
LO_2 Tank Press Sensor	4.2.6.20	2												1				3.900	TA		
LO_2/LH_2 Tank Diff.	4.2.6.21	2												0					TA		
LO_2 Abort Press Valve	4.2.6.22	2												1				0.180			
Vent/Relief Valve	4 2.6.23	1												1				0.600			

*ESS - EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
IDENTIFICATION	CODE	NUMBER PER TUG	COMP SPARE COST ÷ COMP SHIPSET COST	COMP SPARE COST AS FRACTION OF ASSY COST	INITIAL SPARES - COMPONENTS	INITIAL COMP SPARES IN ESS*	AVG SUBASSY COST AS FRACTION OF ASSY COST	INITIAL SPARES - SUBASSYS	TOTAL INITIAL SPARES - SUBASSYS	INITIAL SUBASSY SPARES IN EES	TOTAL INITIAL SPARES IN EES	OPER SPARES - COMPONENTS	OPER COMP SPARES IN ESS	OPER SPARES - SUBASSYS	TOTAL OPER SPARES - SUBASSYS	OPER SUBASSY SPARES IN EES	TOTAL OPER SPARES IN EES	DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EQUIV SUBASSYS	TOTAL DEPOT REPAIR KITS IN EES	TOTAL DEPOT SPARES IN EES
			R	C_j	SI_j	$R \cdot C_j \cdot SI_j$	C_i/N_i	SI_i	ΣSI_i	$C_1 \Sigma SI_i$	EI	SO_j	$R \cdot C_j \cdot SO_j$	SO_i	ΣSO_i	$C_1 \Sigma SO_i$	EO	SO_i	ΣSO_i	$C_1 \Sigma SO_i$	ED
ACPS Eng	4.3			[0.048]		0				0	0		[0.9]		[0.952	[0.050	0.046			[0.014]	0.0007
ACPS Mod	4.3.1	4	0.225	1.0			0.0125					1	0.9		4	0.050			1.110	0.014	
R-4D Auxiliary Thruster	4.3.1.1	(8)												1				0.041			
R-1E Tang. Thruster	4.3.1.2	(8)												1				0.041			
Thruster Isolation Valve	4.3.1.3	(32)												1				0.514			
Thruster Chamber Valve	4.3.1.4	(32)												1				0.514			
ACPS Support	4.4			[0.299]		0				0	0		[0.92]		[0.927]	[0.007]	0.277			[0.840]	0.251
MMH Tank	4.4.1	1	0.9	0.218								1	0.196					0.601		0.131	
N_2O_4 Tank	4.4.2	1		0.218								1	0.196					0.601		0.131	
Tank Bladder	4.4.2.1	2					0.005							1	1	0.005		2.043	TA	0.010	
Relief Valve	4.4.3	3		0.018								1	0.016					0.094		0.002	
Burst Disc	4.4.3.1	(3)					0.002							1		0.002		0.062	TA	0.001	
Ground Check Disconnect	4.4.4	2		0.027								1	0.024					0.246		0.007	
Fill & Drain & Disc	4.4.5	2		0.036								1	0.032					0.125		0.005	
Mod Isolation	4.4.6	8		0.036								1	0.032					0.500		0.018	
Quad Red He Valve	4.4.7	2		0.145								1	0.131					0.125		0.018	
Fill/Drain S/O Valve (He)	4.4.8	1		0.036								1	0.032					0.063		0.002	
Fill/Drain Check Valve (He)	4.4.9	1		0.036								1	0.032					0.122		0.004	
He Pressure Control Mod	4.4.10	1		0.182			0.0096					1	0.164					1.139		0.207	
S/O Valve	4.4.10.1	(4)																(0.250)			
Pressure Regulator	4.4.10.2	(3)																(0.469)			
Pressure Switch	4.4.10.3	(6)																(0.413)			
Filter	4.4.10.4	(3)																(0.002)			
ML Relay	4.4.10.5	(1)																(0.003) (0.001)			
DPDT Switch	4.4.10.6	(2)																8.340			
Pressure Sensors	4.4.11	5	0.180	0.057								2	0.049					4.422	TA	0.225	
Temperature Sensors	4.4.12	7	0.128	0.018								1	0.016						TA	0.080	

*ESS EQUIVALENT SHIPSETS OF THE ASSEMBLY (LEVEL 6)

Appendix D - Task Description Sheets

This appendix contains the baseline time line encompassing all operations for all options and the associated task description sheets. These were used to develop the specific option time lines presented in section 11.3.6.

MDAC CRYOGENIC TUG STUDY

TASK DESCRIPTION SHEETS

9 JULY 1973

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (CONT.)

TASK DESCRIPTION SHEET

TASK TITLE: PREPARE PRELIMINARY M&R SCHEDULE (1.1.1)

TASK OBJECTIVE: To schedule known M&R requirement

TASK PURPOSE: To construct an M&R schedule through review of a Tug's maintenance records and integration of subsystem scheduled M&R requirements.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

127 Data Mgt Test Set

118 C/O Cable Kit (Partial)

148 Signal Conditioning Unit (Partial)

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	16	M-HRS
QUALITY CONTROL	3	M-HRS
SAFETY	3	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: ANALYZE TELEMETRY DATA FOR UNSCHEDULED M&R (1.1.2)

TASK OBJECTIVE: To identify unscheduled M&R requirements.

TASK PURPOSE: To analyze TM data to identify inflight anomalies occurring during the last Tug mission. Fault isolate to LRU and define unscheduled M&R requirements.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT: Hard Copy Via Ground Stations

128 Telemetry Ground Station

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	18	M-HRS
QUALITY CONTROL	6	M-HRS
SAFETY	6	M-HRS
OTHER	8	M-HRS

INTERFACE REQUIREMENTS: Software program to process TM data

TASK DESCRIPTION SHEET

TASK TITLE: UPDATE M&R SCHEDULE (1.1.3)

TASK OBJECTIVE: To establish an integrated M&R schedule.

TASK PURPOSE: To integrate scheduled and unscheduled M&R requirements.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

127 Data Mgt Test Set

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	14	M-HRS
QUALITY CONTROL	4	M-HRS
SAFETY	4	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: RECEIVE TUG AT TPF/PPF (1.1.4)

TASK OBJECTIVE: To physically enter the Tug into M&R cycle. This task and subsequent tasks consider (1) New Tugs, (2) Tugs from Post Landing Operations, and (3) Tugs from Storage.

TASK PURPOSE: To place the Tug in its M&R position at the TPF/PPF and assure a final safe condition prior to initiating M&R actions.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124 Cradles

183 Transporter

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	3	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	1	M-HRS
OTHER	1.5	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PREPARE FOR INSPECTION AND CHECKOUT (1.1.5)

TASK OBJECTIVE: To place the Tug in a condition for Post Flight/Receiving Inspection and C/O

TASK PURPOSE: To position workstands, provide access to installed subsystems and connect/checkout GSE.

121 Comsec Equipment
191 Workstand Kit
175 Static Dessicant Kit
111 APS Breakout Control Box
117 Checkout Access Kit

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

168 Spacecraft Simulator	169 Space Tug Simulator
124 Cradles	148 Signal Cond Unit
183 Transporter	155 Power Sys Test Set
118 Checkout Cable Kit	161 Prop Pneumatic Console
119 Comm Test Set	163 Propellant or Pneumatic Control Console
127 Data Mgt Test Set	
185 Umbilical Kit	149 Orbiter Simulator

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	22.5	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM POST FLIGHT/RECEIVING INSPECTION (1.1.6)

TASK OBJECTIVE: To determine subsystem physical condition, installation integrity and subsystem status where instrumentation is not feasible.

TASK PURPOSE: To identify unscheduled M&R requirements not previously identified.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124 Cradles

183 Transporter

191 Workstand Kit

MANPOWER REQUIREMENTS:

PROPULSION TECH	24	M-HRS
MECHANICAL TECH	24	M-HRS
AVIONICS TECH	8	M-HRS
ENGINEERING	20	M-HRS
QUALITY CONTROL	16	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM POST FLIGHT C/O -- MAIN PROPULSION -- AMBIENT He PRESS. (1.1 7.1

TASK OBJECTIVE: To determine Main Propulsion Status.

TASK PURPOSE: To verify functional integrity and interface of main propulsion components, verify purges, perform leak checks and to calibrate transducers.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	148	Signal Cond Unit
183	Transporter	185	Umbilical Kit
191	Workstand Kit	161	Prop Pneumatic Console
118	Checkout Cable Kit	117	C/O Access Kit
127	Data Mgt Test Set	180	Environ Cooling
119	Comm. Test Set		
155	Power Sys Test Set		

MANPOWER REQUIREMENTS:

PROPULSION TECH	16	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	8.5	M-HRS
ENGINEERING	8.5	M-HRS
QUALITY CONTROL	8.5	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM POST FLIGHT C/O - MAIN PROPULSION - COLD He PRESS. (1.1.7.2)

TASK OBJECTIVE: To determine Main Propulsion Status.

TASK PURPOSE: To verify functional integrity and interface of main propulsion components, verify purges, perform leak checks, and to calibrate transducers.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	148	Signal Cond Unit
183	Transporter	185	Umbilical Kit
191	Workstand Kit	161	Prop Pneumatic Console
118	Checkout Cable Kit	117	C/O Access Kit
127	Data Mgt Test Set	180	Environ Cool Unit
119	Comm Test Set	163	Propellant or Pneumatic ~~Control Con~~sole
155	Power Sys Test Set		

MANPOWER REQUIREMENTS:

PROPULSION TECH	17	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	8.5	M-HRS
ENGINEERING	8.5	M-HRS
QUALITY CONTROL	8.5	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM POST FLIGHT C/O - MAIN PROPULSION - AUTOGENOUS PRESS.(1.1.7 3)

TASK OBJECTIVE: To determine Main Propulsion Status

TASK PURPOSE: To verify functional integrity and interface of main propulsion components, verify purges, perform leak checks, and to calibrate transducers.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	148	Signal Cond Unit
183	Transporter	185	Umbilical Kit
191	Workstand Kit	161	Prop Pneumatic Console
118	Checkout Cable Kit	117	C/O Access Kit
127	Data Mgt Test Set	180	Environ Cool Unit
119	Comm Test Set	163	Prop or Pneumatic Control Console
155	Power Sys Test Set		

MANPOWER REQUIREMENTS:

PROPULSION TECH	17	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	8.5	M-HRS
ENGINEERING	8.5	M-HRS
QUALITY CONTROL	8.5	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM POST FLIGHT C/O -- MAIN PROPULSION -- ZERO NPSH (1.1.7.4)

TASK OBJECTIVE: To determine Main Propulsion Status.

TASK PURPOSE: To verify functional integrity and interface of main propulsion components, verify purges, perform leak checks and to calibrate transducers.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	148	Signal Cond Unit
183	Transporter	185	Umbilical Kit
191	Workstand Kit	161	Prop Pneumatic Console
118	C/O Cable Kit	117	C/O Access Kit
127	Data Mgt Test Set	180	Environ Cool Unit
119	Comm Test Set	163	Prop or Pneumatic Control Console
155	Power Sys Test Set		

MANPOWER REQUIREMENTS:

PROPULSION TECH	16	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	8	M-HRS
ENGINEERING	8	M-HRS
QUALITY CONTROL	8	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM POST FLIGHT C/O -- APS -- MONOPROPELLANT-BLOWDOWN (1.1.7.5)

TASK OBJECTIVE: To determine APS status.

TASK PURPOSE: To verify functional integrity and interface of APS components, perform leak checks

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	161	Prop Pneumatic Console
183	Transporter	127	Data Mgt Test Set
191	Workstand Kit	119	Comm Test Set
163	Prop or Pneu Contr.Cons.	155	Power Sys Test Set
111	ACPS Breakout Box	148	Signal Cond Unit
117	C/O Access Kit	185	Umbilical Kit
118	C/O Cable Kit	180	Environ Cool Unit

MANPOWER REQUIREMENTS:

PROPULSION TECH	14	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	7	M-HRS
ENGINEERING	7	M-HRS
QUALITY CONTROL	7	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM POST FLIGHT C/O -- APS -- MONOPROPELLANT-PRESSURIZED (1.1.7.6)

TASK OBJECTIVE: To determine APS status.

TASK PURPOSE: To verify functional integrity and interfaces of APS components and perform leak checks.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	161	Prop Pneumatic Console
183	Transporter	127	Data Mgt Test Set
191	Workstand Kit	119	Comm Test Set
163	Prop or Pneumatic Control Console	155	Power Sys Test Set
111	ACPS Breakout Box	148	Signal Cond Unit
117	C/O Access Kit	185	Umbilical Kit
118	C/O Cable Kit	180	Environ Cool Unit

MANPOWER REQUIREMENTS:

PROPULSION TECH	26	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	13	M-HRS
ENGINEERING	13	M-HRS
QUALITY CONTROL	13	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM POST FLIGHT C/O -- APS -- BIPROPELLANT (1.1.7.7)

TASK OBJECTIVE: To determine APS status.

TASK PURPOSE: To verify functional integrity and interface of APS components and perform leak checks

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	161	Prop Pneumatic Console
183	Transporter	127	Data Mgt Test Set
191	Workstand Kit	119	Comm Test Set
163	Prop or Pneumatic Control Console	155	Power Sys Test Set
111	ACPS Breakout Box	148	Signal Cond Unit
117	C/O Access Kit	185	Umbilical Kit
118	C/O Cable Kit	180	Environ Cool Unit

MANPOWER REQUIREMENTS:

PROPULSION TECH	26	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	13	M-HRS
ENGINEERING	13	M-HRS
QUALITY CONTROL	13	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM POST FLIGHT C/O -- APS -- CRYOGENIC (1.1.7.8)

TASK OBJECTIVE: To determine APS status

TASK PURPOSE: To verify functional integrity and interface of APS components and perform leak checks, inspect turbo pump bearings and shaft torques

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	161	Prop Pneumatic Console
183	Transporter	127	Data Mgt Test Set
191	Workstand Kit	119	Comm Test Set
163	Prop or Pneumatic Control Console	155	Power Sys Test Set
111	ACPS Breakout Box	148	Signal Cond Unit
117	C/O Access Kit	185	Umbilical Kit
118	C/O Cable Kit	180	Environ Cool Unit

MANPOWER REQUIREMENTS:

PROPULSION TECH	32	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	16	M-HRS
ENGINEERING	16	M-HRS
QUALITY CONTROL	16	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM POST FLIGHT CHECKOUT -- AVIONICS (1.1.7.9)

TASK OBJECTIVE: To determine avionics status

TASK PURPOSE: To verify functional integrity and interface of avionics components and perform required calibration

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

		156	Prim Batt C/O Kit
		121	Comsec Equipt
124	Cradles	148	Signal Cond Unit
183	Transporter	169	Tug Simulator
191	Workstand Kit	144	Lazar Radar C/O Kit
118	Cable Kit	168	Spacecraft Simulator
119	Comm Test Set	174	Star Tracker Sim
127	Data Mgt Test Set	149	Orbiter Simulator
155	Power Sys Test Set	180	Environ Cool Unit

302, 304, 307
Software
Computer
Programs

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	48.5	M-HRS
ENGINEERING	69	M-HRS
QUALITY CONTROL	10	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM POST STORAGE C/O - MAIN PROPULSION - AMBIENT He PRESS. (1.1.8.1)

TASK OBJECTIVE: To determine Main Propulsion Status

TASK PURPOSE: To verify functional integrity and interface of main propulsion components, verify purges, perform leak checks and to calibrate transducers

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	148	Signal Cond Unit
183	Transporter	185	Umbilical Kit
191	Workstand Kit	161	Prop Pneumatic Console
118	Checkout Cable Kit	117	C/O Access Kit
127	Data Mgt Test Set	180	Environ Cooling
119	Comm Test Set		
155	Power Sys Test Set		

MANPOWER REQUIREMENTS:

PROPULSION TECH	60	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	30	M-HRS
ENGINEERING	30	M-HRS
QUALITY CONTROL	30	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM POST STORAGE C/O - MAIN PROPULSION - COLD He PRESS. (1.1.8.2)

TASK OBJECTIVE: To determine Main Propulsion Status

TASK PURPOSE: To verify functional integrity and interface of Main Propulsion components, verify purges, perform leak checks and to calibrate transducers.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	148	Signal Cond Unit
183	Transporter	185	Umbilical Kit
191	Workstand Kit	161	Prop Pneumatic Console
118	Checkout Cable Kit	117	C/O Access Kit
127	Data Mgt Test Set	180	Environ Cool Unit
119	Comm Test Set	163	Prop or Pneumatic Control Console
155	Power Sys Test Set		

MANPOWER REQUIREMENTS:

PROPULSION TECH	68	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	34	M-HRS
ENGINEERING	34	M-HRS
QUALITY CONTROL	34	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM POST STORAGE CHECKOUT - MAIN PROPULSION - AUTOGENOUS PRESS.(1.1.8.3)

TASK OBJECTIVE: To determine Main Propulsion Status

TASK PURPOSE: To verify functional integrity and interface of main propulsion components, verify purges, perform leak checks to calibrate transducers.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	148	Signal Cond Unit
183	Transporter	185	Umbilical Kit
191	Workstand Kit	161	Prop Pneumatic Console
118	Checkout Cable Kit	117	C/O Access Kit
127	Data Mgt Test Set	180	Environ Cool Unit
119	Comm Test Set	163	Prop or Pneumatic Control Console
155	Power Sys Test Set		

MANPOWER REQUIREMENTS:

PROPULSION TECH	54	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	27	M-HRS
ENGINEERING	27	M-HRS
QUALITY CONTROL	27	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM POST STORAGE C/O - MAIN PROPULSION - ZERO NPSH (1.1.8.4)

TASK OBJECTIVE: To determine Main Propulsion Status

TASK PURPOSE: To verify functional integrity and interface of main propulsion components, verify purges, perform leak checks, and to calibrate transducers.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	148	Signal Cond Unit
183	Transporter	185	Umbilical Kit
191	Workstand Kit	161	Prop Pneumatic Console
118	C/O Cable Kit	117	C/O Access Kit
127	Data Mgt Test Set	180	Environ Cool Unit
119	Comm Test Set	163	Prop or Pneumatic Control Console
155	Power Sys Test Set		

MANPOWER REQUIREMENTS:

PROPULSION TECH	52	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	26	M-HRS
ENGINEERING	26	M-HRS
QUALITY CONTROL	26	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM POST STORAGE C/O — APS -- MONOPROPELLANT BLOWDOWN (1.1.8.5)

TASK OBJECTIVE: To determine APS status

TASK PURPOSE: To verify functional integrity and interface of APS components, perform leak checks

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	161	Prop Pneumatic Console
183	Transporter	127	Data Mgt Test Set
191	Workstand Kit	119	Comm Test Set
163	Prop or Pneumatic Control Console	155	Power Sys Test Set
111	ACPS Breakout Box	148	Signal Cond Unit
117	C/O Access Kit	185	Umbilical Kit
118	C/O Cable Kit	180	Environ Cool Unit

MANPOWER REQUIREMENTS:

PROPULSION TECH	22	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	11	M-HRS
ENGINEERING	11	M-HRS
QUALITY CONTROL	11	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM POST STORAGE C/O - APS - MONOPROPELLANT PRESSURIZED (1.1.8.6)

TASK OBJECTIVE: To determine APS status

TASK PURPOSE: To verify functional integrity and interface of APS components and perform leak checks

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	161	Prop Pneumatic Console
183	Transporter	127	Data Mgt Test Set
191	Workstand Kit	119	Comm Test Set
163	Prop or Pneumatic Control Console	155	Power Sys Test Set
111	ACPS Breakout Box	148	Signal Cond Unit
117	C/O Access Kit	185	Umbilical Kit
118	C/O Cable Kit	180	Environ Cool Unit

MANPOWER REQUIREMENTS:

PROPULSION TECH	36	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	18	M-HRS
ENGINEERING	18	M-HRS
QUALITY CONTROL	18	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM POST STORAGE C/O - APS - BIPROPELLANT (1.1.8.7)

TASK OBJECTIVE: To determine APS status

TASK PURPOSE: To verify functional integrity and interface of APS components and perform leak checks

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	161	Prop Pneumatic Console
183	Transporter	163	Prop or Pneumatic Control Console
191	Workstand Kit		
101	ACPS Mod Pres Kit		
111	ACPS Breakout Box		
117	C/O Access Kit		
118	C/O Cable Kit	180	Environ Cool Unit

MANPOWER REQUIREMENTS:

PROPULSION TECH	50	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	25	M-HRS
ENGINEERING	25	M-HRS
QUALITY CONTROL	25	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM POST STORAGE C/O - APS - CRYOGENIC (1.1.8.8)

TASK OBJECTIVE: To determine APS status

TASK PURPOSE: To verify functional integrity and interface of APS components and perform leak checks, inspect turbo pump and shaft torques

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	161	Prop Pneumatic Console
183	Transporter	127	Data Mgt Test Set
191	Workstand Kit	119	Comm Test Set
163	Prop or Pneumatic Control Console	155	Power Sys Test Set
111	ACPS Breakout Box	148	Signal Cond Unit
117	C/O Access Kit	185	Umbilical Kit
118	C/O Cable Kit	180	Environ Cool Unit

MANPOWER REQUIREMENTS:

PROPULSION TECH	84	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	42	M-HRS
ENGINEERING	42	M-HRS
QUALITY CONTROL	42	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM POST STORAGE C/O - AVIONICS (1.1.8.9)

TASK OBJECTIVE: To determine avionics status

TASK PURPOSE: To verify functional integrity and interface of avionics components and perform required calibration.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

302, 304, 305 & 307 COMPUTER PROGRAMS

		156	Prim Batt C/O Kit
		121	Comsec Equipt
		159	Prop Utility Comp Test Set
127	Cradles	148	Signal Cond Unit
183	Transporter	169	Tug Simulator
191	Workstand Kit	149	Orbiter Simulator
118	Cable Kit	168	Spacecraft Simulator
119	Comm Test Set	174	Star Tracker Sim
127	Data Mgt Test Set		
155	Power Sys Test Set	180	Environ Cool Unit

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	327	M-HRS
ENGINEERING	99.5	M-HRS
QUALITY CONTROL	10	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM NEW TUG C/O - MAIN PROPULSION - AMBIENT He PRESS. (1.1.9.1)

TASK OBJECTIVE: To determine Main Propulsion Status

TASK PURPOSE: To verify functional integrity and interface of Main Propulsion components, verify purges, perform leak checks, and to calibrate transducers.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	148	Signal Cond Unit
183	Transporter	185	Umbilical Kit
191	Workstand Kit	161	Prop Pneumatic Console
118	Checkout Cable Kit	117	C/O Access Kit
127	Data Mgt Test Set	180	Environ Cooling
119	Comm Test Set	163	Prop or Pneumatic Control Console
155	Power Sys Test Set		

MANPOWER REQUIREMENTS:

PROPULSION TECH	60	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	30	M-HRS
ENGINEERING	30	M-HRS
QUALITY CONTROL	30	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM NEW TUG C/O - MAIN PROPULSION - COLD He PRESS. (1.1.9.2)

TASK OBJECTIVE: To determine Main Propulsion status

TASK PURPOSE: To verify functional integrity and interface of Main Propulsion components, verify purges, perform leak checks and to calibrate transducers

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	148	Signal Cond Unit
183	Transporter	185	Umbilical Kit
191	Workstand Kit	161	Prop Pneumatic Console
118	Checkout Cable Kit	117	C/O Access Kit
127	Data Mgt Test Set	180	Environ Cool Unit
119	Comm Test Set	163	Prop or Pneumatic Control Console
155	Power Sys Test Set		

MANPOWER REQUIREMENTS:

PROPULSION TECH	68	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	34	M-HRS
ENGINEERING	34	M-HRS
QUALITY CONTROL	34	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM NEW TUG C/O - MAIN PROPULSION - AUTOGENOUS PRESS. (1.1.9.3)

TASK OBJECTIVE: To determine Main Propulsion Status

TASK PURPOSE: To verify functional integrity and interface of Main Propulsion components, verify purges, perform leak checks and to calibrate transducers.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	148	Signal Cond Unit
183	Transporter	185	Umbilical Kit
191	Workstand Kit	161	Prop Pneumatic Console
118	Checkout Cable Kit	117	C/O Access Kit
127	Data Mgt Test Set	180	Environ Cool Unit
119	Comm Test Set	163	Prop or Pneumatic Control Console
155	Power Sys Test Set		

MANPOWER REQUIREMENTS:

PROPULSION TECH	54	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	27	M-HRS
ENGINEERING	27	M-HRS
QUALITY CONTROL	27	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM NEW TUG C/O - MAIN PROPULSION - ZERO NPSH (1.1.9.4)

TASK OBJECTIVE: To determine Main Propulsion Status

TASK PURPOSE: To verify functional integrity and interface of main propulsion components, verify purges, perform leak checks, and to calibrate transducers.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	148	Signal Cond Unit
183	Transporter	185	Umbilical Kit
191	Workstand Kit	161	Prop Pneumatic Console
118	C/O Cable Kit	117	C/O Access Kit
127	Data Mgt Test Set	180	Environ Cool Unit
119	Comm Test Set	163	Prop or Pneumatic Control Console
155	Power Sys Test Set		

MANPOWER REQUIREMENTS:

PROPULSION TECH	52	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	26	M-HRS
ENGINEERING	26	M-HRS
QUALITY CONTROL	26	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM NEW TUG C/O - APS - MONOPROPELLANT BLOWDOWN (1.1.9.5)

TASK OBJECTIVE: To determine APS status

TASK PURPOSE: To verify functional integrity and interface of APS components and perform leak checks.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	161	Prop Pneumatic Console
183	Transporter	127	Data Mgt Test Set
191	Workstand Kit	119	Comm Test Set
163	Prop or Pneumatic Control Console	155	Power Sys Test Set
111	ACPS Breakout Box	148	Signal Cond Unit
117	C/O Access Kit	185	Umbilical Kit
118	C/O Cable Kit	180	Environ Cool Unit

MANPOWER REQUIREMENTS:

PROPULSION TECH	22	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	11	M-HRS
ENGINEERING	11	M-HRS
QUALITY CONTROL	11	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM NEW TUG C/O - APS - MONOPROPELLANT - PRESSURIZED (1.1.9.6)

TASK OBJECTIVE: To determine APS status

TASK PURPOSE: To verify functional integrity and interface of APS components and perform leak checks.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	161	Prop Pneumatic Console
183	Transporter	127	Data Mgt Test Set
191	Workstand Kit	119	Comm Test Set
163	Prop or Pneumatic Control Console	155	Power Sys Test Set
111	ACPS Breakout Box	148	Signal Cond Unit
117	C/O Access Kit	185	Umbilical Kit
118	C/O Cable Kit	180	Environ Cool Unit

MANPOWER REQUIREMENTS:

PROPULSION TECH	36	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	18	M-HRS
ENGINEERING	18	M-HRS
QUALITY CONTROL	18	M-HRS
SAFETY	18	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM NEW TUG C/O - APS - BIPROPELLANT (1.1.9.7)

TASK OBJECTIVE: To determine APS status

TASK PURPOSE: To verify functional integrity and interface of APS components and perform leak checks

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	161	Prop Pneumatic Console
183	Transporter	127	Data Mgt Test Set
191	Workstand Kit	119	Comm Test Set
163	Prop or Pneumatic Control Console	155	Power Sys Test Set
111	ACPS Breakout Box	148	Signal Cond Unit
117	C/O Access Kit	185	Umbilical Kit
118	C/O Cable Kit	180	Environ Cool Unit

MANPOWER REQUIREMENTS:

PROPULSION TECH	50	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	25	M-HRS
ENGINEERING	25	M-HRS
QUALITY CONTROL	25	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM NEW TUG C/O - APS CRYOGENIC (1.1.9.8)

TASK OBJECTIVE: To determine APS status

TASK PURPOSE: To verify functional integrity and interface of APS components, perform leak checks, inspect turbo pump bearings and check shaft torque.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	161	Prop Pneumatic Console
183	Transporter	127	Data Mgt Test Set
191	Workstand Kit	119	Comm Test Set
163	Prop or Pneumatic Control Console	155	Power Sys Test Set
111	ACPS Breakout Box	148	Signal Cond Unit
117	C/O Access Kit	185	Umbilical Kit
118	C/O Cable Kit	180	Environ Cool Unit

MANPOWER REQUIREMENTS:

PROPULSION TECH	84	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	42	M-HRS
ENGINEERING	42	M-HRS
QUALITY CONTROL	42	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM NEW TUG C/O - AVIONICS (1.1.9.9)

TASK OBJECTIVE: To determine avionics status

TASK PURPOSE: To verify functional integrity and interface of avionics components and perform required calibration

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

302, 304, 305 & 307 COMPUTER PROGRAMS

		159	PU Component Test Set
		156	Prim Batt C/O Kit
		121	Comsec Equipt
124	Cradles	148	Signal Cond Unit
183	Transporter	169	Tug Simulator
191	Workstand Kit	148	Orbiter Simulator
118	Cable Kit	168	Spacecraft Simulator
119	Comm Test Set	174	Star Tracker Sim
127	Data Mgt Test Set		
155	Power Sys Test Set	180	Environ Cool Unit

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	48.5	M-HRS
ENGINEERING	69	M-HRS
QUALITY CONTROL	10	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PREPARE/UPDATE M&R SCHEDULE (1.1.10)

TASK OBJECTIVE: To provide final update of M&R schedule prior to accomplishing unscheduled M&R tasks

TASK PURPOSE: Incorporates unscheduled M&R requirements resulting from post flight/receiving inspection and post flight, post storage, and new tug checkout.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT: 127 Data Mgt Test Set

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	14	M-HRS
QUALITY CONTROL	4	M-HRS
SAFETY	4	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM STRUCTURE/MECHANICAL M&R (1.1.11)

TASK OBJECTIVE: To correct structure/mechanical subsystem discrepancies

TASK PURPOSE: This task is primarily concerned with the performance of unscheduled M&R tasks required to maintain/restore the Space Tug to satisfactory condition. The magnitude of this task will vary with the configuration and each individual mission.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124 Cradles

183 Transporter

191 Workstand Kit

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	17	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM PROPULSION M&R (1.1.12)

TASK OBJECTIVE: To corrent Propulsion subsystem discrepancies

TASK PURPOSE: This task is primarily concerned with the performance of unscheduled M&R tasks required to maintain/restore the Space Tug to an operable condition. The magnitude of this task will vary with the configuration and each individual missions.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	160	Prop Comp Repair Kit
183	Transporter		
191	Workstand Kit		
130	Engine Actuation Fixture		
131	Engine Align Kit		
132	Engine Handling Kit		
133	Engine Position Fixture		

MANPOWER REQUIREMENTS:

PROPULSION TECH	14	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM AVIONICS M&R (1.1.13)

TASK OBJECTIVE: To correct avionics subsystem discrepancies

TASK PURPOSE: This task is primarily concerned with the performance of unscheduled M&R tasks required to maintain/restore the Space Tug to an operable condition. The magnitude of this task will vary with the configuration and each individual mission.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

304, 305 & 307 COMPUTER PROGRAMS

124	Cradles	143	Guid & Nav System C/O
183	Transporter		
191	Workstand Kit		
115	Battery Handling Kit	159	PU Test Set
		164	Battery C/O Kit
		174	Star Tracker Test Set
142	Guid & Nav Test Set		

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	32	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: REMOVE M&R GSE (1.1.14)

TASK OBJECTIVE: To clear area around the Tug to permit transfer to prelaunch area.

TASK PURPOSE: To disconnect and remove GSE, required during M&R to a position which permits unobstructed movement of the Tug.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124 Cradles

183 Transporter

191 Workstand Kit

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	4	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	.5	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: RECEIVE FSE AT TPF/PPF (1.1.15)

TASK OBJECTIVE: To physically enter FSE into the M&R cycles. This task and subsequent tasks consider (1) New FSE, (2) FSE from post landing operations and (3) FSE from storage.

TASK PURPOSE: To inventory FSE, prepare routing tags and transfer FSE to appropriate work area.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT: 134 Equipt Van

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	3	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	3	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PREPARE FOR INSPECTION (1.1.16)

TASK OBJECTIVE: Perform those tasks required to facilitate inspection

TASK PURPOSE: Separate tilt table from Tug, clean FSE external surface, position/connect GSE and perform self check.

TASK LOCATION: TPF/KSC and PPF (WTR)

TASK EQUIPMENT:

124	Cradles
183	Transporter
191	Workstand Kit
181	Tilt Table Handling Kit

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	16	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM FSE POST FLIGHT/RECEIVING INSPECTION (1.1.17)

TASK OBJECTIVE: To determine FSE physical condition, installation integrity and FSE status where instrumentation is not feasible.

TASK PURPOSE: To identify unscheduled M&R requirements not previously identified.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

MANPOWER REQUIREMENTS:

PROPULSION TECH	4	M-HRS
MECHANICAL TECH	11.5	M-HRS
AVIONICS TECH	12	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	16	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PREPARE/UPDATE M&R SCHEDULE (1.1.18)

TASK OBJECTIVE: To provide final update of M&R schedule prior to accomplishing unscheduled M&R tasks.

TASK PURPOSE: Incorporates unscheduled M&R requirements resulting from Post Flight/Receiving Inspection and Post Flight, Post Storage, and New Tug Checkout.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT: 127 Data Mgt Test Set
118 C/O Cable Kit (Partial)

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	8.5	M-HRS
QUALITY CONTROL	1.5	M-HRS
SAFETY	1.5	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM FSE M&R (1.1.19)

TASK OBJECTIVE: To correct FSE discrepancies.

TASK PURPOSE: This task is primarily concerned with the unscheduled M&R tasks required to maintain/restore the Tug FSE to a satisfactory condition, however, there are some scheduled M&R tasks such as cleaning fluid umbilicals.

TASK LOCATION: TPF and LOX Clean Facility/KSC and PPF and LOX Clean Facility/WTR

TASK EQUIPMENT: 160 Prop Component Repair Kit

181 Tilt Table Fixture

MANPOWER REQUIREMENTS:

PROPULSION TECH	32	M-HRS
MECHANICAL TECH	16	M-HRS
AVIONICS TECH	16	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PREPARE FOR STORAGE (1.1.20)

TASK OBJECTIVE: To place the Tug in a condition whereby it can be stored with minimum subsystem degradation.

TASK PURPOSE: This task includes battery removal, installation or dessicant package, cleaning the Tug, installing protective covers, etc.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	180	Environ Control Unit
183	Transporter	115	Battery Handling Kit
191	Workstand Kit		
123	Cover-Tug		
120	Component Protective Covers		
175	Static Dessicant Kit		

MANPOWER REQUIREMENTS:

PROPULSION TECH	6	M-HRS
MECHANICAL TECH	24	M-HRS
AVIONICS TECH	2	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PREPARE FOR TRANSPORT (1.1.21)

TASK OBJECTIVE: To place the Tug in a transportable condition

TASK PURPOSE: This task includes closing and securing access panels, and hooking up to a prime mover

TASK LOCATION:

TASK EQUIPMENT:

124	Cradles
183	Transporter
191	Workstand Kit
182	Tractor - Transporter

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	7	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	1	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: TRANSFER TO STORAGE (1.1.22)

TASK OBJECTIVE: To locate the Tug in a designated storage area.

TASK PURPOSE: To move Tug from TPF/PPF to storage area.

TASK LOCATION: TPF to Storage Area/KSC and PPF to Storage Area/WTR

TASK EQUIPMENT:

124	Cradles
183	Transporter
123	Cover-Tug
120	Component Protective Covers
182	Tractor - Transporter

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	4	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	4	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM STORAGE SUPPORT (1.1.23)

TASK OBJECTIVE: To minimize subsystem degradation during storage.

TASK PURPOSE: To perform inspection, servicing and other preventive maintenance tasks, as required.

TASK LOCATION: Designated Storage Area at KSC and WTR

TASK EQUIPMENT:

180 Environ Control Unit
124 Cradles
183 Transporter
123 Cover-Tug
120 Component Protective Covers

MANPOWER REQUIREMENTS:

PROPULSION TECH	4	M-HRS
MECHANICAL TECH	4	M-HRS
AVIONICS TECH	4	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	4	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: REMOVE FROM STORAGE (1.1.24)

TASK OBJECTIVE: Determine Tug physical condition and place Tug in a transportable condition.

TASK PURPOSE: Inspect Tug for general condition, identify subsystem discrepancies and prepare for transport.

TASK LOCATION: Designated Storage Area at KSC and WTR

TASK EQUIPMENT:

124 Cradles

183 Transporter

123 Cover-Tug

120 Component Protective Covers

MANPOWER REQUIREMENTS:

PROPULSION TECH	4	M-HRS
MECHANICAL TECH	4	M-HRS
AVIONICS TECH	4	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	4	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: TRANSFER TO TPF/PPF FOR M&R (1.1.25)

TASK OBJECTIVE: To locate the Tug at the TPF/PPF

TASK PURPOSE: To move Tug to TPF/PPF from storage area.

TASK LOCATION: Storage Area to TPF/KSC and Storage Area to PPF/WTR

TASK EQUIPMENT:

124 Cradles

183 Transporter

123 Cover-Tug

120 Component Protective Covers

182 Tractor - Transporter

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	2	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	2	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: TRANSFER TO PRELAUNCH (1.1.26)

TASK OBJECTIVE: To locate the Tug at the Prelaunch area

TASK PURPOSE: To move Tug from M&R area to Prelaunch area

TASK LOCATION: TPF to VAB/KSC and PPF to VAB/WTR

TASK EQUIPMENT:
124 Cradles
183 Transporter
182 Tractor - Transporter

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	4	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	4	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: POST M&R VERIFICATION (1.2.1)

TASK OBJECTIVE: To assure that Tug subsystems on which M&R has been performed will now function satisfactorily and that the Tug is ready for transfer to prelaunch area.

TASK PURPOSE: To verify that fault detection and isolation of subsystem discrepancies was accurate, M&R tasks were performed correctly, and that performance of M&R tasks have cleared subsystem discrepancies.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124	Cradles	156	Prim Batt C/O Kit
183	Transporter	169	Tug Simulator
191	Workstand Kit		
118	C/O Cable Kit	168	Spacecraft Simulator
127	Data Mgt Test Set	174	Star Tracker Test Set
119	Comm Test Set		
155	Power Sys Test Set	111	APS Breakout Control Box
148	Signal Cond Unit		
185	Umbilical Kit		
161	Prop Pneum Console		
180	Environ Cooling		
159	Prop Util Test Set		

304, 305 & 307 COMPUTER PROGRAMS

MANPOWER REQUIREMENTS:

PROPULSION TECH	2	M-HRS
MECHANICAL TECH	1	M-HRS
AVIONICS TECH	1	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	4	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PERFORM POST M&R VERIFICATION - FSE (1.2.2)

TASK OBJECTIVE: To assure that Tug FSE on which M&R has been performed, will now function satisfactorily and that the Tug is ready for transfer to the prelaunch area.

TASK PURPOSE: To verify that performance of FSE M&R tasks have corrected previously identified discrepancies.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

		181	Tilt Table Handling Kit
118	C/O Cable Kit	185	Umbilical Kit
127	Data Mgt Test Set		
119	Comm Test Set		
155	Power Sys Test Set		
148	Signal Cond Unit		
149	Orbiter Simulator		

MANPOWER REQUIREMENTS:

PROPULSION TECH	4	M-HRS
MECHANICAL TECH	2	M-HRS
AVIONICS TECH	2	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	8	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: RECEIVE FSE FROM M&R (2.1.1)

TASK OBJECTIVE: Assemble flight configuration Flight Support Equipment for transport to Orbiter MCF where it will be installed in the flight vehicle.

TASK PURPOSE: To assemble the total complement of FSE required for the mission. Personnel will receive, check, and load this equipment into a van for transport to the Orbiter for installation.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT: 134 Transport Van

Dollies

Low Boy

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	2	M-HRS
SAFETY	2	M-HRS
OTHER	11	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: RECEIVE TUG FROM M&R (2.1.2)

TASK OBJECTIVE: Receipt of the Tug vehicle from the Maintenance and Refurbishment operations.

TASK PURPOSE: This task initiates the Prelaunch Operations on the Tug vehicle, and includes preparatory work for flight configuration.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

191 Side Workstands

183 Transporter

124 Cradles

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	5.5	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PREPARE TUG FOR PPF TRANSFER (2.1.3)

TASK OBJECTIVE: To prepare the Tug vehicle for transfer to the DOD Payload Processing Facility at KSC for DOD spacecraft work prior to launch.

TASK PURPOSE: To encapsulate the Tug in a protective cover to insure vehicle 100,000 class cleanliness.

TASK LOCATION: TPF/KSC

TASK EQUIPMENT:
123 Tug Covers
Cover Bar
124 Cradles
183 Transporter
191 Workstand Kit

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	13	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: TRANSFER TUG TO PPF (2.1.4.)

TASK OBJECTIVE: To provide the Tug vehicle at the PPF for preflight spacecraft work required for a DOD mission.

TASK PURPOSE: To transfer the Tug vehicle from the TPF to the PPF at KSC.

TASK LOCATION: TPF-to-PPF/KSC

TASK EQUIPMENT:

183 Transporter

124 Cradles

123 Cover-Tug

182 Transporter Tractor

MANPOWER REQUIREMENTS:		
PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	2	M-HRS
SAFETY	0	M-HRS
OTHER	9	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: TRANSFER PAYLOAD TO SPF (2.1.5)

TASK OBJECTIVE: Transfer of the Tug to the Storable Propellant Facility for loading of the Storable Attitude Control Propulsion System

TASK PURPOSE: The Tug and Spacecraft are transfered to this facility to allow loading of the ACPS.

TASK LOCATION: TPT-to-SPF/KSC and WTR

TASK EQUIPMENT:

183	Transporter
182	Tractor- Transporter
123/122	Covers
194	(Security Vehicle)

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	1	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	2	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	9/17	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: STORABLE PROPELLANT SERVICING (2.1.7)

TASK OBJECTIVE: To complete the prelaunch servicing of the storable monopropellant attitude control propulsion system.

TASK PURPOSE: The storable ACPS is purged, loaded, and leak tested at the SPF before transfer to the MCF for Orbiter integration.

TASK LOCATION: SPF/KSC and WTR

TASK EQUIPMENT:

112 APS Loading Access Kit
SCAPE Suits (2)
139 Gas Sampling Equipment
161 Pneumatic Console
113 Propellant Servicer
185 Umbilical Kit
183 Transporter
182 Tractor
123 Covers
109 Portable Cleanliness Tent
192 (Security Vehicle)

MANPOWER REQUIREMENTS:

PROPULSION TECH	40	M-HRS
MECHANICAL TECH	8	M-HRS
AVIONICS TECH	10	M-HRS
ENGINEERING	34	M-HRS
QUALITY CONTROL	18	M-HRS
SAFETY	17	M-HRS
OTHER	2/21	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: STORABLE PROPELLANT SERVICING (2.1.6.a ALTERNATE)

TASK OBJECTIVE: To complete the prelaunch servicing of the storable monopropellant attitude control propulsion system.

TASK PURPOSE: The storable ACPS is purged, loaded, and leak tested at the launch pad with the Tug inside the payload bay, using the T-26 service umbilicals.

TASK LOCATION: Launch Pad/KSC and WTR

TASK EQUIPMENT:

112	APS Loading Access Kit	185	Launch Umb Sys
118	Cable Kit	143	Signal Conditioning Unit
		155	Power Sys Test Set
	SCAPE Suites (2)	176	Subsys Monitor Consoles
139	Gas Sampling Equipment	127	DMST/S
162	Pneumatic Console	128	Telemetry Ground Station
113	Propellant Servicer	163	Prop or Pneu. Cont. Console

MANPOWER REQUIREMENTS:

PROPULSION TECH	36	M-HRS
MECHANICAL TECH	36	M-HRS
AVIONICS TECH	22	M-HRS
ENGINEERING	70	M-HRS
QUALITY CONTROL	22	M-HRS
SAFETY	22	M-HRS
OTHER	6	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: STORABLE PROPELLANT SERVICING (2.1.8)

TASK OBJECTIVE: To complete the prelaunch servicing of the storable bi-propellant attitude control propulsion system.

TASK PURPOSE: The storable ACPS is purged, loaded, and leak tested at the SPF before transfer to the MCF for Orbiter integration.

TASK LOCATION: SPF/KSC and WTR

TASK EQUIPMENT:

112 APS Loading Access Kit

SACPE Suits (2)

139 Gas Sampling Equipment

161 Pneumatic Console

113 Propellant Servicers (2)

185 Umbilical Kit

183 Transporter

182 Tractor

122/123 Covers

109 Portable Cleanliness Tent

192 (Security Vehicle)

MANPOWER REQUIREMENTS:

PROPULSION TECH	88	M-HRS
MECHANICAL TECH	10	M-HRS
AVIONICS TECH	14	M-HRS
ENGINEERING	46	M-HRS
QUALITY CONTROL	23	M-HRS
SAFETY	23	M-HRS
OTHER	2/38	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: STORABLE PROPELLANT SERVICING (2.1.6.b ALTERNATE)

TASK OBJECTIVE: To complete the prelaunch servicing of the storable bipropellant attitude control propulsion system.

TASK PURPOSE: The storable ACPS is purged, loaded, and leak tested at the launch pad, with the Tug inside the payload bay, using the T-26 service umbilicals.

TASK LOCATION: Launch Pad/KSC and WTR

TASK EQUIPMENT:

112	APS Loading Access Kit	146	Launch Umb Sys
118	Cable Kit	148	Signal Conditioning Unit
		155	Power Sys Test Set
	SCAPE Suits (2)	176	Subsys Monitor Consoles
139	Gas Sampling Equipment	127	DMST/S
162	Pneumatic Console	128	Telemetry Ground Station
113	Propellant Servicers (2)	163	Prop or Pneu Cont. Console

MANPOWER REQUIREMENTS:

PROPULSION TECH	54	M-HRS
MECHANICAL TECH	54	M-HRS
AVIONICS TECH	42	M-HRS
ENGINEERING	106	M-HRS
QUALITY CONTROL	32	M-HRS
SAFETY	20	M-HRS
OTHER	26	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PREPARE FOR SPACECRAFT EQUIPMENT (2.2.1.1)

TASK OBJECTIVE: To prepare the Tug and work area for installation of spacecraft equipment for a retrieval mission.

TASK PURPOSE: To assemble the Tug and spacecraft retrieval unique equipment together in one area for prelaunch integration work on the Tug vehicle.

TASK LOCATION: TPF or PPF/KSC and PPF/WTR

TASK EQUIPMENT:

183 Transporter
134 Van
191 Work Stands
124 Cradles
182 Tractor - Transporter

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	1	M-HRS
AVIONICS TECH	1	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	1	M-HRS
SAFETY	0	M-HRS
OTHER	6/6.5	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: INSTALL SPACECRAFT EQUIPMENT (2.2.1.2.a)

TASK OBJECTIVE: To install spacecraft unique equipment for a DOD retrieval mission.

TASK PURPOSE: To complete the spacecraft equipment installation on the Tug vehicle for DOD spacecraft retrieval missions.

TASK LOCATION: PPF/KSC and WTR

TASK EQUIPMENT:

191 Work Stands and Platforms
183 Transporter
150 Payload Adapter Handling Equipment
124 Cradles
182 Tractor - Transporter
184 Tug Support Kit Vertical

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	4	M-HRS
AVIONICS TECH	4	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	2	M-HRS
SAFETY	0	M-HRS
OTHER	3	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: INSTALL SPACECRAFT EQUIPMENT (2.2.1.2.b)

TASK OBJECTIVE: To install spacecraft unique equipment for a NASA spacecraft retrieval mission.

TASK PURPOSE: To complete the spacecraft equipment installation on the Tug vehicle for NASA spacecraft retrieval missions.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:
191 Work Stands and Platforms
183 Transporter
150 Payload Adapter Handling Equipment
124 Cradles

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	2	M-HRS
AVIONICS TECH	2	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	2	M-HRS
SAFETY	0	M-HRS
OTHER	4	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: VERIFY TUG-TO-SPACECRAFT EQUIPMENT INTERFACES (2.2.1.3)

TASK OBJECTIVE: To establish flight readiness of spacecraft interfaces for a retrieval mission.

TASK PURPOSE: To test and verify the spacecraft equipment interfaces operability.

TASK LOCATION: PPF and TPF/KSC and PPF/WTR

TASK EQUIPMENT:

124 Cradles — 155 Power Sys Test Set
183 Transporter — 148 Signal Cond Unit
191 Work Stands and Platforms
168 Spacecraft Simulator
118 C/O Cable Kit — 185 Umbilical Kit
127 Data Mgt Test Set — 149 Orbiter Simulator
119 Comm Test Set — 304, 305 & 307 COMPUTER PROGRAMS

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	15	M-HRS
ENGINEERING	8.5	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PREPARE TUG FOR SPACECRAFT (2.2.2.a.)

TASK OBJECTIVE: To ready the Tug vehicle for spacecraft integration.

TASK PURPOSE: To prepare the work area and perform the final work in preparation for Tug/Spacecraft integration, with no kick stage included in the flight configuration.

TASK LOCATION: TPF and PPF/KSC and PPF/WTR

TASK EQUIPMENT: 191 End Work Stands

183 Transporter

124 Cradles

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	2	M-HRS
AVIONICS TECH	2	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	2	M-HRS
SAFETY	0	M-HRS
OTHER	8	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PREPARE TUG FOR SPACECRAFT (2.2.2.b.)

TASK OBJECTIVE: To ready the Tug vehicle for spacecraft integration.

TASK PURPOSE: To prepare the work area and perform the final work in preparation for Tug/Spacecraft integration, with a kick stage included in the flight configuration.

TASK LOCATION: TPF and PPF/KSC and PPF/WTR

TASK EQUIPMENT:

191	End Work Stands	118	C/O Cable Kit
183	Transporter	118	Signal Cond Unit
124	Cradles	185	Umbilical Kit
168	Spacecraft Sim		
127	DMTS		
155	Power Sys Test Set		
119	Comm Sys Test Set		

MANPOWER REQUIREMENTS:

PROPULSION TECH	4	M-HRS
MECHANICAL TECH	8	M-HRS
AVIONICS TECH	4	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	2	M-HRS
SAFETY	2	M-HRS
OTHER	8	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: MATE TUG AND SPACECRAFT (2.2.3)

TASK OBJECTIVE: To perform the Tug/Spacecraft integration.

TASK PURPOSE: To mate the Tug vehicle and the Spacecraft for a delivery flight.

TASK LOCATION: TPF and PPF/KSC and PPF/WTR

TASK EQUIPMENT: 140 Slings and Tag Lines

191 Work Stands

183 Transporter

124 Cradles

150 P/L Adapter Handling Kit

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	4	M-HRS
AVIONICS TECH	4/7	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	1	M-HRS
SAFETY	1	M-HRS
OTHER	3	M-HRS

INTERFACE REQUIREMENTS:

~~60~~ 0-75

TASK DESCRIPTION SHEET

TASK TITLE: VERIFY TUG-TO-SPACECRAFT INTERFACES (2.2.4)

TASK OBJECTIVE: To verify the launch readiness of the Tug/Spacecraft interfaces.

TASK PURPOSE: To test and establish the flight readiness of the Tug/Spacecraft interfaces (both hardware and software)

TASK LOCATION: TPF and PPF/KSC and PPF/WTR

TASK EQUIPMENT: 127 Telemetry Ground Station

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	21	M-HRS
ENGINEERING	14	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	3	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: VERIFY CLEANLINESS (2.2.5)

TASK OBJECTIVE: To verify the cleanliness of the Tug vehicle and prepare the vehicle for transportation.

TASK PURPOSE: To check the particle counter and verify the cleanliness and then to place the cover on the vehicle to insure the 100,000 class cleanliness is maintained during local transportation of the vehicle.

TASK LOCATION: TPF and PPF/KSC and PPF/WTR

TASK EQUIPMENT:

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	5	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	2	M-HRS
QUALITY CONTROL	5	M-HRS
SAFETY	1	M-HRS
OTHER	14	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: TRANSFER FSE to MCF (2.3.1)

TASK OBJECTIVE: To transfer the Flight Support Equipment to the Orbiter MCF for integration into the Orbiter.

TASK PURPOSE: Transfer the FSE for installation and maintain the cleanliness of that equipment during the transfer.

TASK LOCATION: TPF to MCF/KSC, PPF to MCF/WTR

TASK EQUIPMENT: 134 Equipment Van

192 Security Vehicle

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	3	M-HRS
SAFETY	0	M-HRS
OTHER	15/17	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: INSTALL FSE IN CABIN (CONSOLE) (2.3.2.1.a)

TASK OBJECTIVE: To install the payload console in the Payload Specialist Station of the Orbiter vehicle.

TASK PURPOSE: To install the payload console and verify the interfaces with the Orbiter system.

TASK LOCATION: MCF/KSC and WTR

TASK EQUIPMENT:

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	5	M-HRS
AVIONICS TECH	6	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	1	M-HRS
SAFETY	0	M-HRS
OTHER	3	M-HRS

INTERFACE REQUIREMENTS: Must be completed prior to payload integration into orbiter.

TASK DESCRIPTION SHEET

TASK TITLE: INSTALL FSE IN CABIN (COMSEC) (2.3.2.1.b)

TASK OBJECTIVE: To install the COMSEC required on DOD missions.

TASK PURPOSE: To install the COMSEC into the Orbiter system for the DOD missions.

TASK LOCATION: MCF/KSC and WTR

TASK EQUIPMENT:

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	1.5	M-HRS
AVIONICS TECH	3.5	M-HRS
ENGINEERING	1	M-HRS
QUALITY CONTROL	1	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS: Must be completed prior to 2.3.2.1.a verification.

TASK DESCRIPTION SHEET

TASK TITLE: INSTALL FSE IN PAYLOAD BAY (2.3.2.2)

TASK OBJECTIVE: To prepare the Orbiter for acceptance of the Payload and provide the necessary support equipment in the payload bay.

TASK PURPOSE: To install the Flight Support Equipment required by the payload into the Orbiter Payload Bay.

TASK LOCATION: MCF/KSC and WTR

TASK EQUIPMENT:

MANPOWER REQUIREMENTS:

PROPULSION TECH	1	M-HRS
MECHANICAL TECH	5	M-HRS
AVIONICS TECH	5	M-HRS
ENGINEERING	4	M-HRS
QUALITY CONTROL	4	M-HRS
SAFETY	1	M-HRS
OTHER	14	M-HRS

INTERFACE REQUIREMENTS: Must be completed prior to the physical installation of the payload into the Orbiter payload bay.

TASK DESCRIPTION SHEET

TASK TITLE: VERIFY FSE INTERFACES (2.3.3)

TASK OBJECTIVE: To establish the test readiness of the Payload supplied Flight Support Equipment.

TASK PURPOSE: This is a preliminary step in the launch readiness certification of the payload.

TASK LOCATION: MCF/KSC and WTR

TASK EQUIPMENT:

148 Signal Cond Unit

185 Umbilical Kit

127 DMS Test Set

155 Power Sys Test Set

119 Comm Sys Test Set

118 C/O Cable Kit

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	3	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	1	M-HRS
SAFETY	0	M-HRS
OTHER	4	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: TRANSFER PAYLOAD TO MCF (2.3.4)

TASK OBJECTIVE: To transfer the payload to the Orbiter integration facility.

TASK PURPOSE: To provide the payload at the Orbiter facility designated for the horizontal integration of a payload.

TASK LOCATION: PPF or TPF-to-MCF/KSC, PPF to MCF/WTR

TASK EQUIPMENT:
124 Cradles
183 Transporter
182 Tractor
122 Cover-S/C
123 Cover-Tug
192 Security Vehicle

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	3/5	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PAYLOAD INSTALLATION PREPARATION (2.3.6)

TASK OBJECTIVE: To prepare for the physical installation of the payload into the payload bay.

TASK PURPOSE: To complete all preparatory work required for the payload integration into the payload bay, maintaining cleanliness of the vehicle.

TASK LOCATION: MCF/KSC and WTR

TASK EQUIPMENT:
183 Transporter
124 Cradles
140 Handling Equip

MANPOWER REQUIREMENTS:

PROPULSION TECH	1	M-HRS
MECHANICAL TECH	2	M-HRS
AVIONICS TECH	1	M-HRS
ENGINEERING	2	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	19	M-HRS

INTERFACE REQUIREMENTS:

#0-84

TASK DESCRIPTION SHEET

TASK TITLE: PAYLOAD INSTALLATION MCF (2.3.7)

TASK OBJECTIVE: The physical installation of the payload into the Orbiter payload bay.

TASK PURPOSE: To complete the physical installation of the payload into the Orbiter vehicle.

TASK LOCATION: MCF/KSC and WTR

TASK EQUIPMENT: 140 Handling Equipment

MANPOWER REQUIREMENTS:

PROPULSION TECH	2	M-HRS
MECHANICAL TECH	18	M-HRS
AVIONICS TECH	2	M-HRS
ENGINEERING	2	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	2	M-HRS
OTHER	3	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: VERIFY PAYLOAD-TO-SHUTTLE INTERFACES (2.3.9)

TASK OBJECTIVE: Establish the readiness of the payload/Shuttle interfaces prior to entering the launch operations phase.

TASK PURPOSE: Test and validate the interfaces (hardware and software) between the payload and the Orbiter vehicle. This is the final payload test before the integrated systems test.

TASK LOCATION: MCF/KSC and WTR

TASK EQUIPMENT:

161 Prop Pneu Console	148 Signal Cond Unit
185 Umbilical Kit	163 Prop or Pneu Cont Console
117 C/O Access Kit	301, 305, 307 COMPUTER PROGRAMS
127 DMS Test Set	
155 Power Sys Test Set	
119 Comm Sys Test Set	
118 C/O Cable Kit	

MANPOWER REQUIREMENTS:

PROPULSION TECH	27	M-HRS
MECHANICAL TECH	8	M-HRS
AVIONICS TECH	18	M-HRS
ENGINEERING	36	M-HRS
QUALITY CONTROL	18	M-HRS
SAFETY	0	M-HRS
OTHER	8	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: ORBITER/PAYLOAD INTEGRATED SYSTEM TEST (2.4.1)

TASK OBJECTIVE: Establish the launch readiness of the integrated launch vehicle and payload before releasing the payload for pad and flight operations.

TASK PURPOSE: To validate the integrated system integrity prior to the final launch operations.

TASK LOCATION: Launch Pad/KSC and WTR

TASK EQUIPMENT:

148	Signal Conditioning Unit	185	Launch Umbilical Sys
176	Subsys Monitor Console	155	Power Sys Test Set
118	C/O Cable Kit	129	Digit. Events Rec.
128	Telemetry Ground Station	189	Voice & Timing Sys
127	DMS Test Set	190	Wide Bond Rec.
		301, 305, 307	COMPUTER PROGRAMS
145	Launch Console		

MANPOWER REQUIREMENTS:

PROPULSION TECH	8	M-HRS
MECHANICAL TECH	36	M-HRS
AVIONICS TECH	18	M-HRS
ENGINEERING	30	M-HRS
QUALITY CONTROL	24	M-HRS
SAFETY	4	M-HRS
OTHER	8	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: MONITOR STORABLE ACPS (2.4.1.a)

TASK OBJECTIVE: To continually verify the integrity of the storable ACPS, from integration through launch.

TASK PURPOSE: To respond to safety requirements to assure the integrity of the storable ACPS and verify no leakage in the system.

TASK LOCATION: MCF, VAB, PAD/KSC and WTR

TASK EQUIPMENT:
- 176 Subsys Monitoring Console
- 179 Signal Conditioning Unit
- 146 Launch Umbilical System
- 118 C/O Cable Kit
- 155 Power Sys Test Set
- 127 DMS Test Set
- 128 Telemetry Ground Station

MANPOWER REQUIREMENTS:

PROPULSION TECH	84	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	84	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: TUG SERVICE AT PAD (2.4.2.a)

TASK OBJECTIVE: To complete the umbilical hookup at the launch pad of the Tug unique umbilicals.

TASK PURPOSE: To prepare for the launch pad prelaunch servicing of the Tug vehicle and establish the umbilical system integrity in that area.

TASK LOCATION: Launch Pad/KSC and WTR

TASK EQUIPMENT:
185 Launch Umbilical Sys — 162 Prop Pneu Console
118 C/O Cable Kit — 117 C/O Access Kit
148 Signal Conditioning Unit
176 Subsys Monitor Console — 163 Prop or Pneu Cont. Console
127 DMS Test Set
155 Power Sys Test Set
128 DDAS GND Station

MANPOWER REQUIREMENTS:

PROPULSION TECH	4	M-HRS
MECHANICAL TECH	2	M-HRS
AVIONICS TECH	6	M-HRS
ENGINEERING	6	M-HRS
QUALITY CONTROL	2.5	M-HRS
SAFETY	1.5	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: TUG SERVICE AT PAD (NON CRYO)(2.4.2.b)

TASK OBJECTIVE: Perform the final prelaunch servicing on the Tug vehicle for the non-cryogenic systems.

TASK PURPOSE: Complete the prelaunch servicing for the Tug vehicle pneumatic system.

TASK LOCATION: Launch Pad/KSC and WTR

TASK EQUIPMENT:

158 Prop Loading Console	162 Prop Pneu Console
176 Subsys Monitor Console	129 Digit Events Recorder
148 Signal Conditioning Unit	128 Telemetry Ground Station
118 C/O Cable Kit	163 Prop or Pneu Cont. Console
155 Power Sys Test Set	
127 DMS Test Set	305, 306 COMPUTER PROGRAMS
185 Launch Umbilical Sys	

MANPOWER REQUIREMENTS:

PROPULSION TECH	8	M-HRS
MECHANICAL TECH	13	M-HRS
AVIONICS TECH	13	M-HRS
ENGINEERING	6	M-HRS
QUALITY CONTROL	3	M-HRS
SAFETY	3	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: TUG SERVICE AT PAD (CRYO) (2.4.3)

TASK OBJECTIVE: Perform the final prelaunch servicing on the Tug cryogenic system.

TASK PURPOSE: To complete the prelaunch activities for the Tug vehicle including:

a. Cryogenic System Purges

b. Cryogenic Loading and Replenish

c. Final Software Constants Loaded

TASK LOCATION: Launch Pad/KSC and WTR

TASK EQUIPMENT:

125 Cryo Loading Complex — 185 Launch Umbilical Sys

162 Prop Pneu Console

176 Subsys Monitor Console — 129 Digit Events Recorder

148 Signal Conditioning Unit — 128 Telemetry Ground Station

305, 306 COMPUTER PROGRAMS

118 C/O Cable Kit

155 Power Sys Test Set — 163 Prop or Pneu Cont. Console

127 DMS Test Set

MANPOWER REQUIREMENTS:

PROPULSION TECH	10	M-HRS
MECHANICAL TECH	16	M-HRS
AVIONICS TECH	16	M-HRS
ENGINEERING	8	M-HRS
QUALITY CONTROL	6	M-HRS
SAFETY	2	M-HRS
OTHER	6	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: TUG SERVICE AT PAD (CRYO) (2.4.3.a)

TASK OBJECTIVE: Final activation of the Tug fuel cells*

TASK PURPOSE: To complete the prelaunch activation of the Tug fuel cells

TASK LOCATION: Launch Pad/KSC and WTR

TASK EQUIPMENT:
148 Signal Conditioning Unit — 125 Cryo Loading Complex
176 Subsys Monitor Console — 185 Launch Umbilical Sys
118 C/O Cable Kit
127 DMS Test Set
155 Power Sys Test Set
129 Digit Events Recorder
128 Telemetry Ground Station

MANPOWER REQUIREMENTS:

PROPULSION TECH	3	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	3	M-HRS
ENGINEERING	6	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	3	M-HRS

INTERFACE REQUIREMENTS: *Applies to only those configurations with fuel cells included.

TASK DESCRIPTION SHEET

TASK TITLE: TUG SERVICE AT PAD (CRYO) (2.4.3.b)

TASK OBJECTIVE: Final loading of cold helium system of the Tug*

TASK PURPOSE: To complete the prelaunch activities of the Tug cold helium pressurization system.

TASK LOCATION: Launch Pad/KSC and WTR

TASK EQUIPMENT:

	162 Prop Pneu Console
176 Subsys Monitor Console	129 Digit Events Recorder
148 Signal Conditioning Unit	128 Telemetry Ground Station
118 C/O Cable Kit	147 LH_2-He Heat Exchanger
155 Power Sys Test Set	125 Cryo Loading Complex
127 DMS Test Set	163 Prop or Pneu Cont Console
185 Launch Umbilical Sys	

MANPOWER REQUIREMENTS:

PROPULSION TECH	4	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	2	M-HRS
ENGINEERING	6	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS: *Applies only to those vehicles using the cold helium option.

TASK DESCRIPTION SHEET

TASK TITLE: FINAL CHECKS AT PAD (2.4.4)

TASK OBJECTIVE: To monitor final launch redlined parameters.

TASK PURPOSE: To establish the launch readiness compliance of the Tug vehicle.

TASK LOCATION: LCC/KSC and WTR

TASK EQUIPMENT:
176 Subsys Monitor Console — 129 Digit Events Recorder
179 Terminal Room Equip — 189 Voice & Time Sys
146 Launch Umbilical Sys — 190 Wideband Rec.
118 C/O Cable Kit
155 Power Sys Test Set
127 DMS Test Set
128 Telemetry Ground Station

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	154	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	0	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: REMOVE PAYLOAD (PAD) (2.4.5)

TASK OBJECTIVE: To remove a payload from the payload bay of the Orbiter at the Launch Pad

TASK PURPOSE: Required for payload changeout. Assumes the cleanliness protection will be provided for the payload being removed.

TASK LOCATION: Launch Pad/KSC and WTR

TASK EQUIPMENT:
191 Work Platforms
123 Cover-Tug
140 Handling Equip
183 Transporter
124 Cradles
182 Transporter Tractor

MANPOWER REQUIREMENTS:

PROPULSION TECH	4	M-HRS
MECHANICAL TECH	10	M-HRS
AVIONICS TECH	4	M-HRS
ENGINEERING	4	M-HRS
QUALITY CONTROL	3	M-HRS
SAFETY	3	M-HRS
OTHER	23	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PAYLOAD INSTALLATION OR REMOVAL PREPS (PAD) (2.4.6)

TASK OBJECTIVE: Prepare for the removal or installation of a payload into the Orbiter payload bay at the launch pad.

TASK PURPOSE: To provide the physical access and the environmental protection required for on-pad payload changeout.

TASK LOCATION: Launch Pad/KSC and WTR

TASK EQUIPMENT: 191 Work Platforms

MANPOWER REQUIREMENTS:

PROPULSION TECH	0.5	M-HRS
MECHANICAL TECH	0.5	M-HRS
AVIONICS TECH	0.5	M-HRS
ENGINEERING	0.5	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	2	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: PAYLOAD INSTALLATION (PAD) (2.4.7)

TASK OBJECTIVE: To install a payload into the payload bay of the Orbiter at the launch pad.

TASK PURPOSE: The vertical installation of a payload during the payload change-out operation.

TASK LOCATION: Launch Pad/KSC and WTR

TASK EQUIPMENT: 117 C/O Access Kit

~~140 Handling Equipment~~

184 Tug Support Kit Vertical

191 Workstand Kit

MANPOWER REQUIREMENTS:		
PROPULSION TECH	2	M-HRS
MECHANICAL TECH	15	M-HRS
AVIONICS TECH	2	M-HRS
ENGINEERING	2	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	2	M-HRS
OTHER	5	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: TRANSFER PAYLOAD TO PAD (2.4.8)

TASK OBJECTIVE: To transfer a new payload to the launch pad for payload changeout.

TASK PURPOSE: To provide a clean payload at the launch pad during payload changeout.

TASK LOCATION: Launch Pad/KSC and WTR

TASK EQUIPMENT:

124 Cradles
122 Cover-Spacecraft
123 Cover-Tug
140 Handling Equip
154 Portable Cover-Purge Unit
182 Tractor
183 Transporter

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	4	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	4	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	24 /28	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: TUG GROUND SAFING AT SAFING AREA (3.1.1)

TASK OBJECTIVE: To vent, drain, and purge the cryogenic systems of the Space Tug, including high pressure gas vessels.

TASK PURPOSE: To place the cryogenic systems in a "safe" state and to prepare these systems for any required maintenance action.

TASK LOCATION: Shuttle Safing Area/KSC or WTR

TASK EQUIPMENT: 191 Workstands

161 Prop Pneu Console

Hydrogen Gas Disposal System 163 Prop or Pneu Cont. Console

139 Gas Sampling Equipment

118 C/O Cable Kit Partial

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	8	M-HRS
ENGINEERING	6	M-HRS
QUALITY CONTROL	8	M-HRS
SAFETY	8	M-HRS
OTHER	20	M-HRS

NO LIQUID RESIDUALS

INTERFACE REQUIREMENTS: The Shuttle must remain at the Safing Area until completion of task. Task assumes successful safing completion on-orbit.

TASK DESCRIPTION SHEET

TASK TITLE: TUG GROUND SAFING AT SAFING AREA (3.1.1.a)

TASK OBJECTIVE: To vent, drain, and purge the cryogenic systems of the Space Tug, including high pressure gas vessels.

TASK PURPOSE: To place the cryogenic systems in a "safe" state for handling of the Tug, and to prepare these systems for any required maintenance action.

TASK LOCATION: Shuttle Safing Area/KSC of WTR

TASK EQUIPMENT: 191 Workstands

185 Umbilical Kit

161 Prop Pneu Console

Hydrogen Gas Disposal System 126 Cryo Tank Trucks

139 Gas Sampling Equipment 163 Prop or Pneu Cont. Console

118 C/O Cable Kit (Partial)

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	12	M-HRS
ENGINEERING	10	M-HRS
QUALITY CONTROL	10	M-HRS
SAFETY	10	M-HRS
OTHER	20	M-HRS

LIQUID RESIDUALS

INTERFACE REQUIREMENTS: The Shuttle must remain at the Safing Area until completion of task.

TASK DESCRIPTION SHEET

TASK TITLE: TRANSFER TUG TO SPF (3.1.2)

TASK OBJECTIVE: Transfer of the Space Tug to the Storable Propellant Facility.

TASK PURPOSE: To provide the Tug at the Facility location where the storable propellant ACPS can be placed in a "safe" state.

TASK LOCATION: MCF to SPF/KSC and WTR

TASK EQUIPMENT: 123 Tug Cover

183 Transporter

182 Tractor

124 Cradles

191 Workstands

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	1	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	2	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	9/17	M-HRS

INTERFACE REQUIREMENTS: NONE

TASK DESCRIPTION SHEET

TASK TITLE: TUG ACPS SAFING (3.1.3.a)

TASK OBJECTIVE: To vent, drain, purge, and leak check the bipropellant ACPS of the Space Tug.

TASK PURPOSE: To place the ACPS in a "safe" state and to prepare the system for any required maintenance action. Also, to identify a system which is leaking and will require unscheduled maintenance.

TASK LOCATION: Storable Propellant Facility/KSC and WTR

TASK EQUIPMENT: 112 APS Loading Access Kit

Two Personnel Protection (SCAPE)

139 Gas Sampling Equipment — 191 Workstand

161 Pneumatic Console — 148 Signal Cond Unit

113 Two Propellant Servicers — 109 Portable Cleanliness Tent

MANPOWER REQUIREMENTS:

PROPULSION TECH	16	M-HRS
MECHANICAL TECH	35	M-HRS
AVIONICS TECH	42	M-HRS
ENGINEERING	22	M-HRS
QUALITY CONTROL	21	M-HRS
SAFETY	8	M-HRS
OTHER		M-HRS

INTERFACE REQUIREMENTS: The Tug must remain at the SPF until completion of task. The cryogenic system must be safed prior to this operation.

TASK DESCRIPTION SHEET

TASK TITLE: TUG ACPS SAFING (3.1.3.a Alternate)

TASK OBJECTIVE: To vent, drain, purge, and leak check the bipropellant ACPS of the Space Tug.

TASK PURPOSE: To place the ACPS in a "safe" state and to prepare the system for any required maintenance action. Also, to identify system requirements from leaking for unscheduled maintenance.

TASK LOCATION: Safing Area/KSC and WTR

TASK EQUIPMENT:
112 APS Loading Access Kit
191 Workstands
2 Personnel Protection (SCAPE)
139 Gas Sampling Equipment
109 Portable Cleanliness Tent
161 Pneumatic Console
163 Prop or Pneu. Cont. Console
113 2 Propellant Servicers

MANPOWER REQUIREMENTS:

PROPULSION TECH	16	M-HRS
MECHANICAL TECH	35	M-HRS
AVIONICS TECH	42	M-HRS
ENGINEERING	22	M-HRS
QUALITY CONTROL	21	M-HRS
SAFETY	15	M-HRS
OTHER	22	M-HRS

INTERFACE REQUIREMENTS: The Shuttle must remain at the safing area for this operation.

TASK DESCRIPTION SHEET

TASK TITLE: TUG ACPS SAFING (3.1.3.b)

TASK OBJECTIVE: To vent, drain, purge, and leak check the monopropellant ACPS of the Space Tug

TASK PURPOSE: To place the ACPS in a "safe" state and to prepare the system for any required maintenance action. Also, to identify a system leak failure which will require unscheduled maintenance.

TASK LOCATION: Storable Propellant Facility/KSC and WTR

TASK EQUIPMENT:

112 APS Loading Access Kit
183 Transporter
182 Tractor
Two Personnel Protection (SCAPE)
123 Covers
139 Gas Sampling Equipment
109 Portable Cleanliness Tent
161 Pneumatic Console
192 Security Vehicle
113 Propellant Servicer

MANPOWER REQUIREMENTS:

PROPULSION TECH	10	M-HRS
MECHANICAL TECH	24	M-HRS
AVIONICS TECH	15	M-HRS
ENGINEERING	16	M-HRS
QUALITY CONTROL	10	M-HRS
SAFETY	5	M-HRS
OTHER		M-HRS

INTERFACE REQUIREMENTS: The Tug must remain at the SPF until completion of task. The cryogenic system must be safed prior to this operation.

TASK DESCRIPTION SHEET

TASK TITLE: TUG ACPS SAFING (3.1.3.b Alternate)

TASK OBJECTIVE: To vent, drain, purge, and leak check the monopropellant ACPS of the Space Tug.

TASK PURPOSE: To place the ACPS in a "safe" state and to prepare the system for any required maintenance action. Also, to identify a system leak failure which will require unscheduled maintenance.

TASK LOCATION: Safing Area/KSC and WTR

TASK EQUIPMENT:
112 APS Loading Access Kit
2 Personnel Protection (SCAPE)
139 Gas Sampling Equipment
161 Pneumatic Console
163 Prop or Pneu. Cont. Console
113 ACPS Servicer

MANPOWER REQUIREMENTS:

PROPULSION TECH	10	M-HRS
MECHANICAL TECH	24	M-HRS
AVIONICS TECH	15	M-HRS
ENGINEERING	16	M-HRS
QUALITY CONTROL	10	M-HRS
SAFETY	10	M-HRS
OTHER	14	M-HRS

INTERFACE REQUIREMENTS: The Shuttles must remain at the Safing Area for this operation.

TASK DESCRIPTION SHEET

TASK TITLE: TRANSFER TUG AND SPACECRAFT TO SPF (3.1.4)

TASK OBJECTIVE: Transfer of returning payload to the Storable Propellant Facility.

TASK PURPOSE: To provide the payload at the facility location where the storable propellant systems can be placed in a "safe" state.

TASK LOCATION: MCF to SPF/KSC and WTR

TASK EQUIPMENT:

123 Tug Cover

122 Spacecraft Cover

183 Transporter

182 Tractor

124 Cradles

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	1	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	2	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	12/22	M-HRS

INTERFACE REQUIREMENTS: Manpower requirements are a function of Spacecraft safing requirements.

TASK DESCRIPTION SHEET

TASK TITLE: TUG SAFING (3.1.5.a)

TASK OBJECTIVE: To vent, drain, purge, and leak check the bipropellant ACPS of the Space Tug with the spacecraft attached.

TASK PURPOSE: To place the ACPS in a "safe" state and to prepare the system for any required maintenance action. Also, to identify a system which is leaking and will require unscheduled maintenance.

TASK LOCATION: Storable Propellant Facility/KSC and WTR

TASK EQUIPMENT:

112 APS Loading Access Kit
185 Umbilical Kit
183 Transporter
113 APS Servicer
182 Tractor
Two Personnel Protection (SCAPE)
123 Covers
139 Gas Sampling Equipment
163 Prop or Pneu. Cont. Console
161 Pneumatic Console
192 Security Vehicle
113 Two Propellant Servicers

MANPOWER REQUIREMENTS:

PROPULSION TECH	16	M-HRS
MECHANICAL TECH	35	M-HRS
AVIONICS TECH	42	M-HRS
ENGINEERING	22	M-HRS
QUALITY CONTROL	21	M-HRS
SAFETY	14	M-HRS
OTHER	14/47	M-HRS

INTERFACE REQUIREMENTS: Cryogenic system safing must be completed before this operation.

TASK DESCRIPTION SHEET

TASK TITLE: TUG SAFING (3.1.5.b)

TASK OBJECTIVE: To vent, drain, purge, and leak check the monopropellant ACPS of the Space Tug with the spacecraft attached.

TASK PURPOSE: To place the ACPS in a "safe" state and to prepare the system for any required maintenance action. Also, to identify a system leak which will require unscheduled maintenance.

TASK LOCATION: Storable Propellant Facility/KSC and WTR

TASK EQUIPMENT:
112 APS Loading Access Kit
183 Transporter
182 Tractor
Two Personnel Protection (SCAPE) — 123/122 Covers
139 Gas Sampling Equipment — 163 Prop or Pneumatic Cont. Console
161 Pneumatic Console
113 Propellant Servicer

MANPOWER REQUIREMENTS:

PROPULSION TECH	10	M-HRS
MECHANICAL TECH	24	M-HRS
AVIONICS TECH	15	M-HRS
ENGINEERING	16	M-HRS
QUALITY CONTROL	10	M-HRS
SAFETY	10	M-HRS
OTHER	14/34	M-HRS

INTERFACE REQUIREMENTS: Cryo safing must be completed prior to this activity.

TASK DESCRIPTION SHEET

TASK TITLE: RECOVER TUG AT SAFING AREA (3.2.2)

TASK OBJECTIVE: To remove returning Tug from the Space Shuttle Orbiter Vehicle

TASK PURPOSE: Remove the Space Tug to initiate the Tug ground turnaround operations and release the Orbiter for its turnaround operations.

TASK LOCATION: Safing Area/KSC and WTR

TASK EQUIPMENT:
183 Transporter
182 Tractor - Transporter
2 Overhead Cranes
140 4 Tag Lines
123 Tug Cover
191 Work Stands
124 Cradles

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	10	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	6	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	2	M-HRS
OTHER	29	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: RECOVER TUG AT MCF (3.2.3)

TASK OBJECTIVE: To remove the returning Tug from the Space Shuttle Orbiter Vehicle.

TASK PURPOSE: Remove the Space Tug from the Orbiter to initiate the Tug turnaround operations and release the Orbiter for its turnaround operations.

TASK LOCATION: MCF/KSC and WTR

TASK EQUIPMENT:
183 Transporter
Two Overhead Cranes
140 Four Tag Lines
123 Tug Cover
191 Work Stands
124 Cradles

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	10	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	6	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	2	M-HRS
OTHER	23	M-HRS

INTERFACE REQUIREMENTS: Task must be completed by G.E.T. of 25 hours to free Shuttle for its operations.

TASK DESCRIPTION SHEET

TASK TITLE: RECOVER TUG AND SPACECRAFT AT SAFING AREA (3.2.4)

TASK OBJECTIVE: To remove the returning payload from the Space Shuttle Orbiter Vehicle.

TASK PURPOSE: Remove the payload to initiate the payload turnaround operations and release the Orbiter for its turnaround operations.

TASK LOCATION: Safing Area/KSC and WTR

TASK EQUIPMENT: 183 Transporter 124 Cradles

2 Overhead Cranes

140 4 Tag Lines

123 Tug Cover

122 Spacecraft Cover

191 Workstands

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	15	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	6	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	2	M-HRS
OTHER	30	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: RECOVER TUG AND SPACECRAFT AT MCF (3.2.5)

TASK OBJECTIVE: To remove the returning Payload from the Space Shuttle Orbiter Vehicle

TASK PURPOSE: Remove the Payload from the Orbiter to initiate the payload turnaround operations and release the Orbiter for its turnaround operations.

TASK LOCATION: MCF/KSC and WTR

TASK EQUIPMENT: 183 Transporter

Two Overhead Cranes 124 Cradles

140 Four Tag Lines

123 Tug Cover

122 Spacecraft Cover

191 Work Stands

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	15	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	6	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	2	M-HRS
OTHER	24	M-HRS

INTERFACE REQUIREMENTS: Task must be completed by working time of 25 hours to free Shuttle for its operation.

TASK DESCRIPTION SHEET

TASK TITLE: RECOVER FSE (CABIN) EQUIPMENT (CONSOLE) (3.2.6.a)

TASK OBJECTIVE: To remove the display and control equipment from the returning Orbiter Vehicle.

TASK PURPOSE: To initiate the turnaround operations of the Tug Display and Control Equipment and release the Orbiter for its turnaround operations.

TASK LOCATION: MCF/KSC and WTR

TASK EQUIPMENT: 134 Equipment Van

191 Workstands

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	5	M-HRS
AVIONICS TECH	2	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	3	M-HRS
SAFETY	0	M-HRS
OTHER	10	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: RECOVER FSE (CABIN) EQUIPMENT (COMSEC) (3.2.6.b)

TASK OBJECTIVE: To remove DOD COMSEC FSE from the Orbiter cabin.

TASK PURPOSE: To initiate the turnaround operations of the COMSEC equipment and release the Orbiter for its turnaround operations.

TASK LOCATION: MCF/KSC and WTR

TASK EQUIPMENT: 134 Equipment Van
191 Workstands

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	1.5	M-HRS
AVIONICS TECH	1.5	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	0.5	M-HRS
SAFETY	0	M-HRS
OTHER	2	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: RECOVER FSE (PAYLOAD BAY) EQUIPMENT (3.2.7)

TASK OBJECTIVE: To remove the Tug Flight Support Equipment from the payload bay of the Orbiter Vehicle.

TASK PURPOSE: To initiate the turnaround operations of the Flight Support Equipment and release the Orbiter for its turnaround operations.

TASK LOCATION: MCF/KSC and WTR

TASK EQUIPMENT: 191 Workstands

134 Equipment Van

MANPOWER REQUIREMENTS:

PROPULSION TECH	1	M-HRS
MECHANICAL TECH	5	M-HRS
AVIONICS TECH	5	M-HRS
ENGINEERING	3	M-HRS
QUALITY CONTROL	3	M-HRS
SAFETY	2	M-HRS
OTHER	19	M-HRS

INTERFACE REQUIREMENTS: Operations must be completed prior to Shuttle working time of 26 hours.

TASK DESCRIPTION SHEET

TASK TITLE: TRANSFER FSE TO PPF (3.2.8)

TASK OBJECTIVE: Transfer of Tug DOD Flight Support Equipment to the Payload Processing Facility

TASK PURPOSE: To allow required turnaround operations on the DOD Flight Support Equipment

TASK LOCATION: MCF to PPF/KSC

TASK EQUIPMENT:
134 Equipment Van
192 Security Vehicle

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	[illegible]%
MECHANICAL TECH	0	[illegible]%
AVIONICS TECH	0	[illegible]%
ENGINEERING	0	[illegible]%
QUALITY CONTROL	1	[illegible]%
SAFETY	0	[illegible]%
OTHER	6/10	[illegible]%

INTERFACE REQUIREMENTS: Requires airlock operation to [illegible] cleanliness

TASK DESCRIPTION SHEET

TASK TITLE: TRANSFER FSE TO TPF (3.2.9)

TASK OBJECTIVE: To transfer Flight Support Equipment to the Tug Processing Facility

TASK PURPOSE: To initiate the ground turnaround operations on the Flight Support Equipment.

TASK LOCATION: MCF or PPF to TPF/KSC

TASK EQUIPMENT: 134 Equipment Van

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	1	M-HRS
SAFETY	0	M-HRS
OTHER	10	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: TRANSFER FSE TO PPF (3.2.10)

TASK OBJECTIVE: To transfer FSE to the Payload Processing Facility

TASK PURPOSE: To initiate Tug vehicle FSE turnaround operations

TASK LOCATION: MCF-to-PPF/WTR

TASK EQUIPMENT: 134 Equipment Van

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	0	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	1	M-HRS
SAFETY	0	M-HRS
OTHER	10/14	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: TRANSFER TUG AND SPACECRAFT TO PPF (3.3.1)

TASK OBJECTIVE: Transfer the returning DOD payload to the payload processing facility at KSC

TASK PURPOSE: To allow the returning DOD payload to begin demating and maintenance and refurbishment operations and to release the NASA Tug for TPF operations.

TASK LOCATION: PPF/KSC

TASK EQUIPMENT:

183 Transporter

182 Tractor

123 Tug Cover

122 Spacecraft Cover

192 Security Vehicle

124 Cradles

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	2	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	2	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	10/14	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: DEMATE TUG AND SPACECRAFT (3.3.2)

TASK OBJECTIVE: To separate the returning Tug and spacecraft.

TASK PURPOSE: To allow recycle operations to begin on the Tug and the spacecraft.

TASK LOCATION: TPF/KSC and PPF/WTR

TASK EQUIPMENT:

191 Workstands
Overhead Crane
Spacecraft Slings
183 Transporter
124 Cradles

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	3	M-HRS
AVIONICS TECH	3	M-HRS
ENGINEERING	1	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	1	M-HRS
OTHER	4	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: TRANSFER TUG TO TPF (3.3.3)

TASK OBJECTIVE: To transfer the returning Tug to the Tug Processing Facility

TASK PURPOSE: To allow the recycle operations to begin on the Tug vehicle.

TASK LOCATION: KSC

TASK EQUIPMENT: 183 Transporter

182 Tractor

123 Tug Cover

Overhead Crane

124 Cradles

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	3	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	4	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	13	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: RECOVER SPACECRAFT EQUIPMENT (3.3.4)

TASK OBJECTIVE: To recover DOD peculiar spacecraft equipment on a delivery mission.

TASK PURPOSE: To remove DOD spacecraft equipment to "declassify" the Tug vehicle prior to recycle operations in the TPF.

TASK LOCATION: PPF/KSC

TASK EQUIPMENT:

183 Transporter
191 Work Stands
Overhead Crane
123 Tug Covers
124 Cradles

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	2	M-HRS
AVIONICS TECH	1	M-HRS
ENGINEERING	0.5	M-HRS
QUALITY CONTROL	3	M-HRS
SAFETY	0	M-HRS
OTHER	8	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: TRANSFER TUG TO PPF (3.3.5)

TASK OBJECTIVE: Transfer Tug to the DOD Payload Processing Facility

TASK PURPOSE: For DOD Payload Peculiar Equipment removal at KSC to initiate turnaround operations of the Tug at WTR.

TASK LOCATION: MCF-to-PPF/KSC

TASK EQUIPMENT: 183 Transporter

182 Tractor

123 Tug Cover

124 Cradles

192 Security Vehicle

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	2	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	2	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	10/14	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: TRANSFER TUG AND SPACECRAFT TO TPF (3.3.6)

TASK OBJECTIVE: Transfer the returning payload to the Tug processing facility.

TASK PURPOSE: To allow the returning payload to begin demating and maintenance and refurbishment operations.

TASK LOCATION: KSC

TASK EQUIPMENT: 183 Transporter

182 Tractor

123 Tug Cover

122 Spacecraft Cover

124 Cradles

Overhead Crane

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	3	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	4	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	13/17	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: DEMATE TUG AND SPACECRAFT (3.3.7)

TASK OBJECTIVE: To separate the returning Tug and DOD spacecraft

TASK PURPOSE: To allow recycle operations to begin on the Tug and the spacecraft.

TASK LOCATION: Payload Processing Facility/KSC

TASK EQUIPMENT:

191 Workstands
124 Cradles
Overhead Crane
140 Handling Kit
Spacecraft Slings
183 Transporter
Airlock
123 Tug Covers
122 Spacecraft Cover

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	4	M-HRS
AVIONICS TECH	1.5	M-HRS
ENGINEERING	1.5	M-HRS
QUALITY CONTROL	1.5	M-HRS
SAFETY	3	M-HRS
OTHER	10.5	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: RECOVER SPACECRAFT EQUIPMENT (3.3.8)

TASK OBJECTIVE: To recover spacecraft peculiar equipment following a delivery mission.

TASK PURPOSE: To remove special spacecraft equipment from the Tug prior to recycle operations in the PPF.

TASK LOCATION: PPF/WTR and TPF/KSC

TASK EQUIPMENT: 183 Transporter

191 Side Work Stands

124 Cradles

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	1.5	M-HRS
AVIONICS TECH	0.5/2.5	M-HRS
ENGINEERING	0	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	3	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: TRANSFER TUG TO PPF (3.3.9)

TASK OBJECTIVE: To transfer the returning Tug to the Payload Processing Facility

TASK PURPOSE: To allow the recycle operations to begin on the Tug vehicle.

TASK LOCATION: WTR

TASK EQUIPMENT:
183 Transporter
182 Tractor
133 Tug Covers
Overhead Crane
Airlock
124 Cradles

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	3	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	4	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	13/17	M-HRS

INTERFACE REQUIREMENTS:

TASK DESCRIPTION SHEET

TASK TITLE: TRANSFER TUG AND SPACECRAFT TO PPF (3.3.10)

TASK OBJECTIVE: Transfer the returning Payload to the Payload Processing Facility.

TASK PURPOSE: To allow the returning payload to begin demating and maintenance and refurbishment operations.

TASK LOCATION: WTR

TASK EQUIPMENT: 183 Transporter

182 Tractor

123 Tug Cover

122 Spacecraft Cover

Overhead Crane

Airlock

124 Cradles

MANPOWER REQUIREMENTS:

PROPULSION TECH	0	M-HRS
MECHANICAL TECH	3	M-HRS
AVIONICS TECH	0	M-HRS
ENGINEERING	4	M-HRS
QUALITY CONTROL	0	M-HRS
SAFETY	0	M-HRS
OTHER	13/17	M-HRS

INTERFACE REQUIREMENTS:

TASK TIMELINES

FOR

THE CRYOGENIC TUG

GROUND AND LAUNCH OPERATIONS

13 JULY 1973

NOTE: The timelines enclosed utilized the following skill breakdown notation as furnished by NASA:

a. Propulsion Technicians
b. Mechanical/Structural/Thermal Technicians
c. Avionics Technicians
d. Engineering
e. Quality Control
f. Safety
g. Other

PRELIMINARY TASK TIMELINES

TASK	MANNING REQUIREMENTS: QUANTITY A	B	C	D	E	F	G	MAN-HOURS A	B	C	D	E	F	G
1.1 MAINTENANCE														
1.1.1 Prepare Preliminary $\overline{M}$ & $\overline{R}$ Schedule	0	0	0	3	1	1	0	0	0	0	16	3	3	0
1.1.2 Analyze T/M for Unscheduled $\overline{M}$ & $\overline{R}$	0	0	0	3	1	1	1	0	0	0	18	6	6	8
1.1.3 Update $\overline{M}$ & $\overline{R}$ Schedule	0	0	0	3	1	1	0	0	0	0	14	4	4	0
1.1.4 Receive Tug at TPF/PPF	0	3	0	0	0	2	3	0	3	0	0	0	1	1.5
1.1.5 Prepare for Inspection & C/O	0	6	0	0	0	0	0	0	22.5	0	0	0	0	0
1.1.6 Perform Post Flight/Receiving Inspection	3	3	2	3	2	0	0	24	24	8	20	16	0	0
1.1.7.1 Post Flight Checkout - Main Propulsion Pressurization-Ambient Helium & GH_2 Bleed	2	0	1	1	1	0	0	16	0	8	8	8	0	0
1.1.7.2 Post Flight Checkout - Main Propulsion Pressurization - Cold Helium & GH_2 Bleed	2	0	1	1	1	0	0	17	0	8.5	8.5	8.5	0	0
1.1.7.3 Post Flight Checkout - Main Propulsion Pressurization - Autogenous (All engine Bleed)	2	0	1	1	1	0	0	17	0	8.5	8.5	8.5	0	0
1.1.7.4 Post Flight Checkout - Main Propulsion Zero NPSH	2	0	1	1	1	0	0	16	0	8	8	8	0	0
1.1.7.5 Post Flight Checkout - APS Subsystem Monopropellant - Blowdown	2	0	1	1	1	0	0	14	0	7	7	7	0	0

	Quantity A	Quantity B	Quantity C	Quantity D	Quantity E	Quantity F	Quantity G	Man-Hours A	Man-Hours B	Man-Hours C	Man-Hours D	Man-Hours E	Man-Hours F	Man-Hours G
1.1.7.6 Post Flight Checkout - APS Subsystem Monopropellant - Pressurized	2	0	1	1	1	0	0	26	0	13	13	13	0	0
1.1.7.7 Post Flight Checkout - APS Subsystem Bi-Propellant	2	0	1	1	1	0	0	26	0	13	13	13	0	0
1.1.7.8 Post Flight Checkout - APS Subsystem Cryogenic	2	0	1	1	1	0	0	32	0	16	16	16	0	0
1.1.7.9 Post Flight Checkout - Avionics	0	0	2	2	1	0	0	0	0	48.5	69	10	0	0
1.1.8.1 Post Storage Checkout - Main Propulsion Pressurization = Ambient Helium & GH_2 Bleed	2	0	1	1	1	0	0	60	0	30	30	30	0	0
1.1.8.2 Post-Storage Checkout - Main Propulsion Pressurization = Cold Helium & GH_2 Bleed	2	0	1	1	1	0	0	68	0	34	34	34	0	0
1.1.8.3 Post-Storage Checkout - Main Propulsion Pressurization = Autogenous (All Engine Bleed)	2	0	1	1	1	0	0	54	0	27	27	27	0	0
1.1.8.4 Post Storage Checkout - Main Propulsion Zero NPSH	2	0	1	1	1	0	0	52	0	26	26	26	0	0
1.1.8.5 Post Storage Checkout - APS Subsystem Monopropellant - Blowdown	2	0	1	1	1	0	0	22	0	11	11	11	0	0
1.1.8.6 Post Storage Checkout - APS Subsystem Monopropellant - Pressurized	2	0	1	1	1	0	0	36	0	18	18	18	0	0
1.1.8.7 Post Storage Checkout - APS Subsystem Bi-propellant	2	0	1	1	1	0	0	50	0	25	25	25	0	0
1.1.8.8 Post Storage Checkout - APS Subsystem Cryogenic	2	0	1	1	1	0	0	84	0	42	42	42	0	0

	Quantity A	Quantity B	Quantity C	Quantity D	Quantity E	Quantity F	Quantity G	Man-Hours A	Man-Hours B	Man-Hours C	Man-Hours D	Man-Hours E	Man-Hours F	Man-Hours G
1.1.8.9 Perform Post-Storage C/O - Avionics	0	0	2	2	1	0	0	0	0	327	99.5	10	0	0
1.1.9.1 New Tug Checkout - Main Propulsion Pressurization = Ambient Helium & GH_2 Bleed	2	0	1	1	1	0	0	60	0	30	30	30	0	0
1.1.9.2 New Tug Checkout - Main Propulsion Pressurization = Cold Helium & GH_2 Bleed	2	0	1	1	1	0	0	68	0	34	34	34	0	0
1.1.9.3 New Tug Checkout - Main Propulsion Pressurization = Autogenous (All Engine Bleed)	2	0	1	1	1	0	0	54	0	27	27	27	0	0
1.1.9.4 New Tug Checkout - Main Propulsion Zero NPSH	2	0	1	1	1	0	0	52	0	26	26	26	0	0
1.1.9.5 New Tug Checkout - Aps Subsystem Monopropellant - Blowdown	2	0	1	1	1	0	0	22	0	11	11	11	0	0
1.1.9.6 New Tug Checkout - APS Subsystem Monopropellant - Pressurized	2	0	1	1	1	0	0	36	0	18	18	18	0	0
1.1.9.7 New Tug Checkout - APS Subsystem Bi-propellant	2	0	1	1	1	0	0	50	0	25	25	25	0	0
1.1.9.8 New Tug Checkout - APS Subsystem Cryogenic	2	0	1	1	1	0	0	84	0	42	42	42	0	0
1.1.9.9 New Tug Checkout - Avionics	0	0	2	2	1	0	0	0	0	48.5	69	10	0	0
1.1.10 Prepare/Update $\overline{M}$ & $\overline{R}$ Schedule	0	0	0	3	1	1	0	0	0	0	14	4	4	0
1.1.11 Perform Structure/Mech. $\overline{M}$ & $\overline{R}$	0	6.8	0	0	0	0	0	0	17	0	0	0	0	0
1.1.12 Perform Propulsion $\overline{M}$ & $\overline{R}$	2.3	0	0	0	0	0	0	14	0	0	0	0	0	0
1.1.13 Perform Avionics $\overline{M}$ & $\overline{R}$	0	0	4	0	0	0	0	0	0	32	0	0	0	0

	QUANTITY							MAN-HOURS						
	A	B	C	D	E	F	G	A	B	C	D	E	F	G
1.1.14 Remove $\overline{M}$ & $\overline{R}$ GSE	0	4	0	0	1	0	0	0	4	0	0	.5	0	0
1.1.15 Receive FSE at TPF/PPF	0	3	0	0	0	0	3	0	3	0	0	0	0	3
1.1.16 Prepare For Inspection	0	4	0	0	0	0	0	0	16	0	0	0	0	0
1.1.17 Perform FSE Post Flight/Receiving Insp.	2	4	3	0	2	0	0	4	11.5	12	0	16	0	0
1.1.18 Prepare/Update $\overline{M}$ & $\overline{R}$ Schedule	0	0	0	3	1	1	0	0	0	0	8.5	1.5	1.5	0
1.1.19 Perform FSE $\overline{M}$ & $\overline{R}$	2	1	1	0	0	0	0	32	16	16	0	0	0	0
1.1.20 Prepare for Storage	2	4	2	0	0	0	0	6	24	2	0	0	0	0
1.1.21 Prepare for Transport	0	4	0	0	0	0	2	0	7	0	0	0	0	1
1.1.22 Transfer to Storage	0	2	0	0	0	0	2	0	4	0	0	0	0	4
1.1.23 Perform Storage Support	1	1	1	0	1	0	0	4	4	4	0	4	0	0
1.1.24 Remove From Storage	1	1	1	0	1	0	0	4	4	4	0	4	0	0
1.1.25 Transfer to TPF/PPF for $\overline{M}$ & $\overline{R}$	0	2	0	0	0	0	2	0	2	0	0	0	0	2
1.1.26 Transfer to Prelaunch	0	2	0	0	0	0	2	0	4	0	0	0	0	4
1.2 POST MAINTENANCE CHECKOUT														
1.2.1 Post $\overline{M}$ & $\overline{R}$ Verification	1	1	1	0	3	0	0	2	1	1	0	4	0	0
1.2.2 Perform Post M & R Verification - FSE	1	1	1	0	3	0	0	4	2	2	0	8	0	0
2.1 TUG SYSTEM & INTEGRATED SYSTEM CHECKOUT														
2.1.1 Receive FSE from $\overline{M}$ & $\overline{R}$	0	0	0	0	1	1	5	0	0	0	0	2	2	11
2.1.2 Receive Tug from $\overline{M}$ & $\overline{R}$	0	0	0	0	0	0	4	0	0	0	0	0	0	5.5

	QUANTITY							MAN-HOURS						
	A	B	C	D	E	F	G	A	B	C	D	E	F	G
2.1.3 Prepare Tug for PPF Transfer	0	0	0	0	0	0	6	0	0	0	0	0	0	13
2.1.4 Transfer Tug to PPF	0	0	0	0	1	0	6	0	0	0	0	2	0	9
2.1.5 Transfer Payload to S.P.F.	0	1	0	1	0	0	6	0	1	0	2	0	0	9
2.1.6a Deleted														
2.1.6b Deleted														
2.1.7 ACPS Loading (Mono)	4	2	1	2	1	1	1	40	8	10	34	18	17	2
2.1.8 ACPS Loading (Biprop)	4	2	1	2	1	1	1	88	10	14	46	23	23	2
2.2 SPACECRAFT/TUG MATE														
2.2.1.1 Prepare for Spacecraft Equipment	0	1	1	0	1	0	4	0	1	1	0	1	0	6
2.2.1.2a Install Spacecraft Equipment	0	2	2	0	1	0	3	0	4	4	0	2	0	3
2.2.1.2b Install Spacecraft Equipment	0	1	1	0	1	0	3	0	2	2	0	2	0	4
2.2.1.3 Verify Tug-To-Spacecraft Equipment Interfaces	0	0	3	2	0	0	0	0	0	15	8.5	0	0	0
2.2.2.a Prepare Tug for Spacecraft	0	2	2	0	2	0	4	0	2	2	0	2	0	8
2.2.2.b Prepare Tug for Spacecraft	2	4	2	0	1	1	6	4	8	4	0	2	2	8
2.2.3 Mate Tug and Spacecraft	0	2	2	0	1	1	3	0	4	4	0	1	1	3
2.2.4 Verify Tug-To-Spacecraft Interfaces	0	0	3	2	0	0	1	0	0	21	14	0	0	3
2.2.5 Verify Cleanliness	0	5	0	1	1	1	5	0	5	0	2	5	1	14
2.3 SHUTTLE/TUG MATE														
2.3.1 Transfer FSE to MCF	0	0	0	0	1	0	7	0	0	0	0	3	0	15
2.3.2.1a (Console) Install FSE in Cabin	0	2	2	0	1	0	3	0	5	6	0	1	0	3

	QUANTITY							MAN-HOURS						
	A	B	C	D	E	F	G	A	B	C	D	E	F	G
2.3.2.1b (Comsec) Install FSE in Cabin	0	1	1	1	1	0	0	0	1.5	3.5	1	1	0	0
2.3.2.2 Install FSE in Payload Bay	1	4	4	2	2	1	5	1	5	5	4	4	1	14
2.3.3 Verify FSE Interfaces	0	0	3	0	1	0	4	0	0	3	0	1	0	4
2.3.4 Transfer Payload to MCF	0	0	0	0	0	0	2	0	0	0	0	0	0	3
2.3.6 Payload Installation Preps	1	2	1	2	0	0	5	1	2	1	2	0	0	19
2.3.7 Payload Installation MCF	1	5	1	1	0	1	3	2	18	2	2	0	2	3
2.3.9 Verify Payload-To-Shuttle Interfaces	3	1	2	4	2	0	2	27	8	18	36	18	0	8
2.4 COUNTDOWN														
2.4.1 Orbiter/Payload Integrated System Test	2	4	2	4	3	1	2	8	36	18	30	24	4	8
2.4.1a Monitor Storable ACPS	1	0	0	0	0	1	0	84	0	0	0	0	84	0
2.4.2a Tug Service at Pad	3	2	5	4	2	1	0	4	2	6	6	2.5	1.5	0
2.4.2b Tug Service at Pad (Non-Cryo)	3	4	4	2	1	1	0	8	13	13	6	3	3	0
2.4.3 Tug Service at Pad (Cryo's)	2	4	4	4	3	1	2	10	16	16	8	6	2	6
2.4.3a Tug Service at Pad (Cryo's)	2	0	2	4	0	0	2	3	0	3	6	0	0	3
2.4.3b Tug Service at Pad (Cryo's)	2	0	1	4	0	0	0	4	0	2	6	0	0	0
2.4.4 Final Checks at Pad	0	0	0	7	0	0	0	0	0	0	154	0	0	0
2.4.5 Remove Payload (Pad)	2	5	2	2	1	1	7	4	10	4	4	3	3	23
2.4.6 Payload Installation or Removal Preps (Pad)	1	1	1	1	0	0	4	0.5	0.5	0.5	0.5	0	0	2

	Quantity A	Quantity B	Quantity C	Quantity D	Quantity E	Quantity F	Quantity G	Man-Hours A	Man-Hours B	Man-Hours C	Man-Hours D	Man-Hours E	Man-Hours F	Man-Hours G
2.4.7 Payload Installation (Pad)	1	5	1	1	0	1	5	2	15	2	2	0	2	5
2.4.8 Transfer Payload to Pad	0	2	0	2	0	0	6	0	4	0	4	0	0	24
3.1 SAFE AND SECURE														
3.1.1 Tug Ground Safing at Safing Area	0	0	2	3	1	1	4	0	0	8	6	8	8	20
3.1.1.a Tug Ground Safing at Safing Area	0	0	2	3	1	1	4	0	0	12	10	10	10	20
3.1.2 Transfer Tug to SPF	0	1	0	1	0	0	6	0	1	0	2	0	0	9
3.1.3.a Tug ACPS Safing	2	5	3	4	2	1	0	16	35	42	22	21	8	0
3.1.3.b Tug ACPS Safing	2	6	3	4	2	1	0	10	24	15	16	10	5	0
3.1.4 Transfer Tug and S/C to SPF	0	1	0	1	0	0	6	0	1	0	2	0	0	12
3.1.5a Deleted														
3.1.5b Deleted														
3.1.6 ACPS Safing (Mono)	4	4	1	2	1	1	1	26	16	.5	15	8	6	1
3.1.7 ACPS Safing (BiProp)	4	4	1	2	1	1	1	36	24	1	22	11	11	2
3.2 SHUTTLE/TUG DEMATE														
3.2.3 Recover Tug at MCF	0	5	0	1	0	1	6	0	10	0	6	0	2	23
3.2.5 Recover Tug and S/C at MCF	0	5	0	1	0	1	6	0	15	0	6	0	2	24
3.2.6.a Recover FSE (Cabin) Equipment (Console)	0	2	1	0	1	0	4	0	5	2	0	3	0	10
3.2.6.b Recover FSE (Cabin) Equipment (COMSEC)	0	1	1	0	1	0	2	0	1.5	1.5	0	0.5	0	2
3.2.7 Recover FSE (Payload Bay) Equipment	1	4	4	2	2	1	6	1	5	5	3	3	2	19
3.2.8 Transfer FSE to PPF	0	0	0	0	1	0	4	0	0	0	0	1	0	6
3.2.9 Transfer FSE to TPF	0	0	0	0	1	0	7	0	0	0	0	1	0	10
3.2.10 Transfer FSE to P[illegible]	0	0	0	0	1	0	7	0	0	0	0	1	0	10

	Quantity A	Quantity B	Quantity C	Quantity D	Quantity E	Quantity F	Quantity G	Man-Hours A	Man-Hours B	Man-Hours C	Man-Hours D	Man-Hours E	Man-Hours F	Man-Hours G
3.3 SPACECRAFT/TUG DEMATE														
3.3.1 Transfer Tug and S/C to PPF	0	1	0	1	0	0	5	0	2	0	2	0	0	10
3.3.2 Demate Tug and Spacecraft	0	2	2	1	0	1	4	0	3	3	1	0	1	4
3.3.3 Transfer Tug to TPF	0	1	0	1	0	0	6	0	3	0	4	0	0	13
3.3.4 Recover Spacecraft Equipment	0	2	1	1	1	0	4	0	2	1	0.5	3	0	8
3.3.5 Transfer Tug to PPF	0	1	0	1	0	0	5	0	2	0	2	0	0	10
3.3.6 Transfer Tug and Spacecraft to TPF	0	1	0	1	0	0	5	0	3	0	4	0	0	13
3.3.7 Demate Tug and Spacecraft	0	3	1	1	1	1	4	0	4	1.5	1.5	1.5	3	10.5
3.3.8 Recover Spacecraft Equipment	0	2	1	0	0	0	3	0	1	0.5	0	0	0	3
3.3.9 Transfer Tug to PPF	0	1	0	1	0	0	6	0	3	0	4	0	0	13
3.3.10 Transfer Tug and Spacecraft to PPF	0	1	0	1	0	0	5	0	3	0	4	0	0	13
ALTERNATE TIMELINES														
2.1.6.a Storable Propellant Servicing	4	4	2	6	2	2	2	36	36	22	70	22	22	6
2.1.6.b Storable Propellant Servicing	4	4	3	8	3	2	4	54	54	42	106	32	20	26
3.1.3.a Tug ACPS Safing	2	5	3	4	2	2	4	16	35	42	22	21	15	22
3.1.3.b Tug ACPS Safing	2	6	3	4	2	1	4	10	24	15	16	10	10	14
3.2.2 Recover Tug at Safing Area	0	5	0	1	0	1	6	0	10	0	6	0	2	29
3.2.4 Recover Tug and Spacecraft at Safing Area	0	6	0	1	0	1	6	0	15	0	6	0	2	30

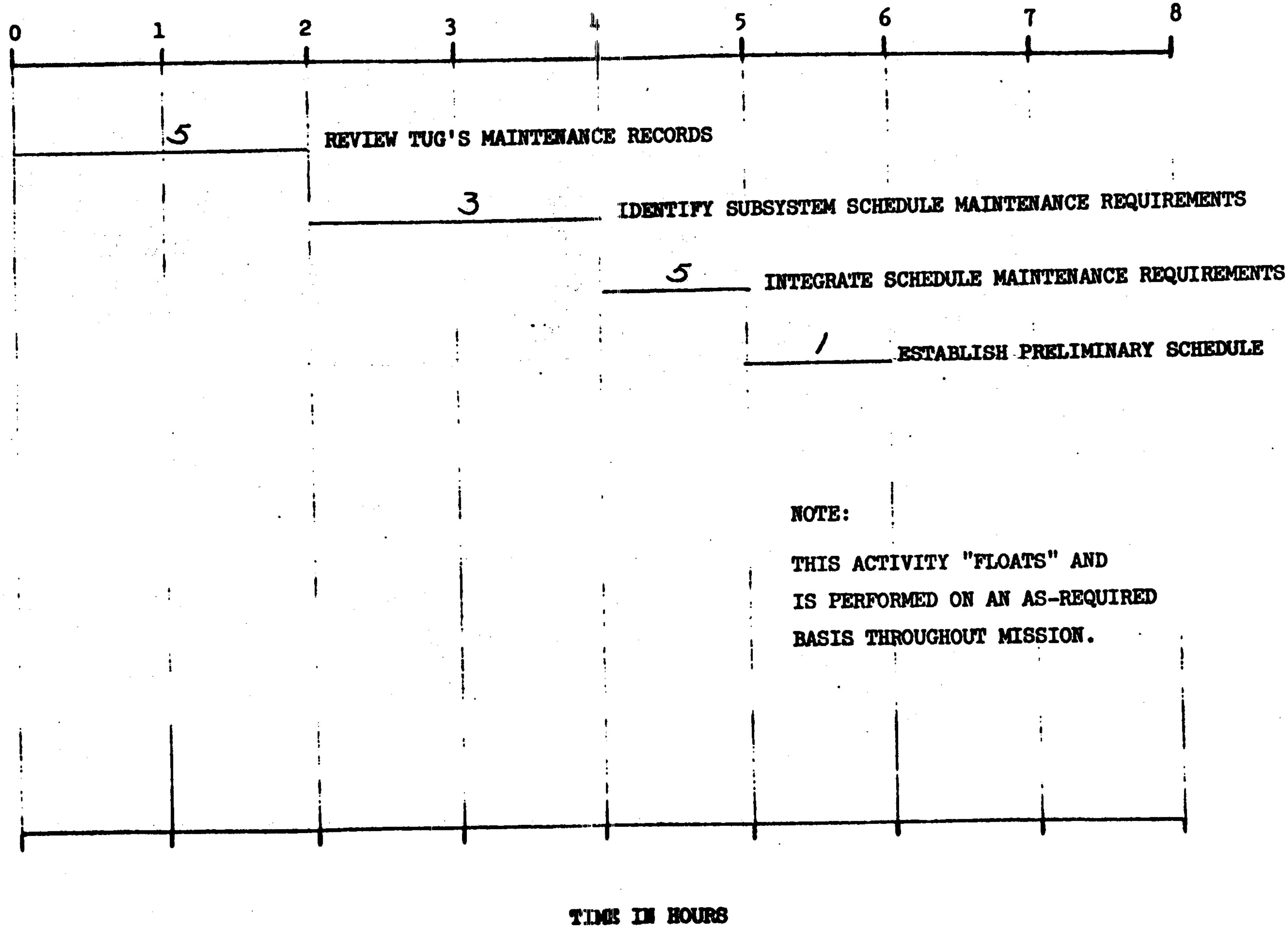
BASELINE TIMELINES

FOR THE

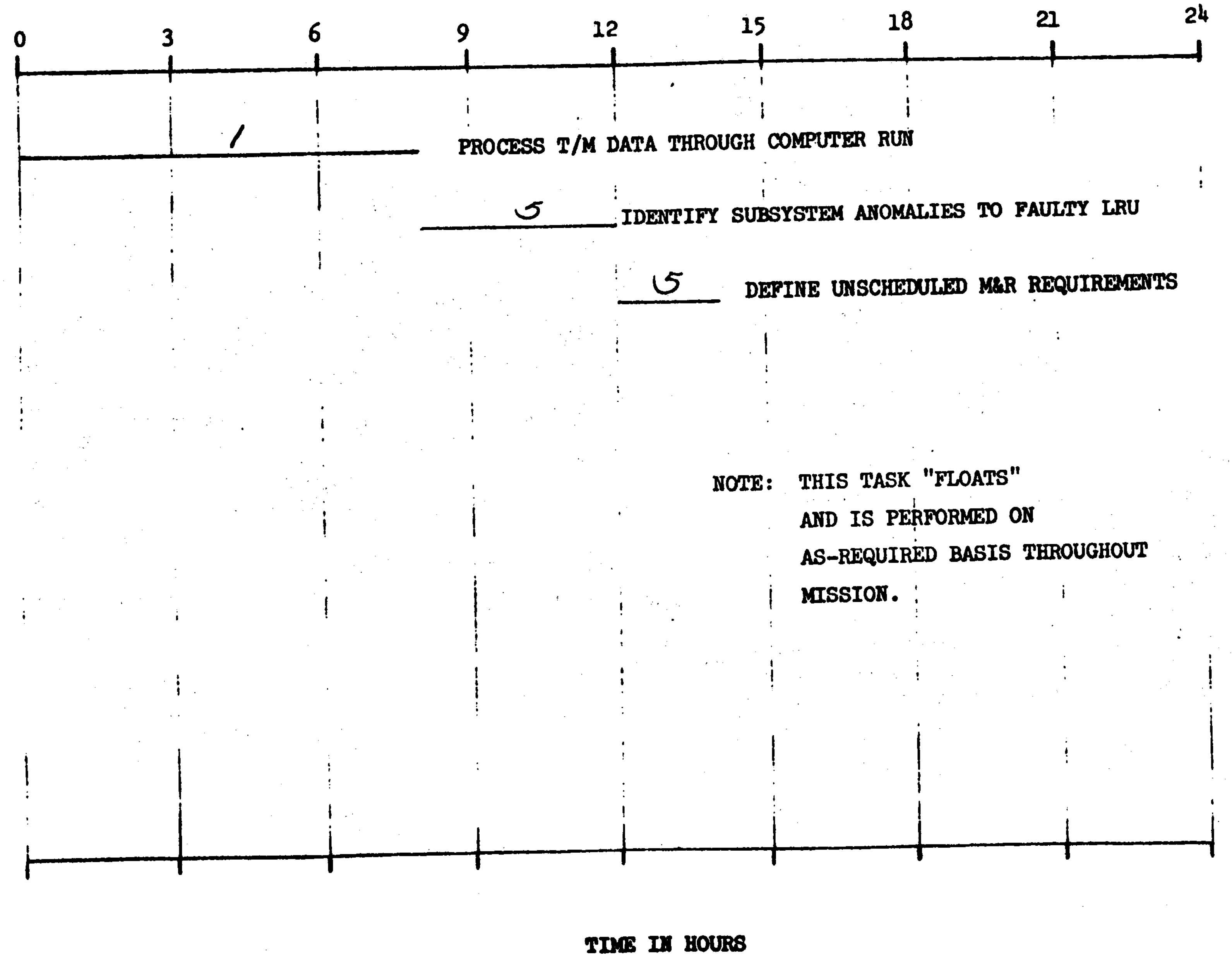
MDAC

CRYOGENIC TUG GROUND OPERATIONS

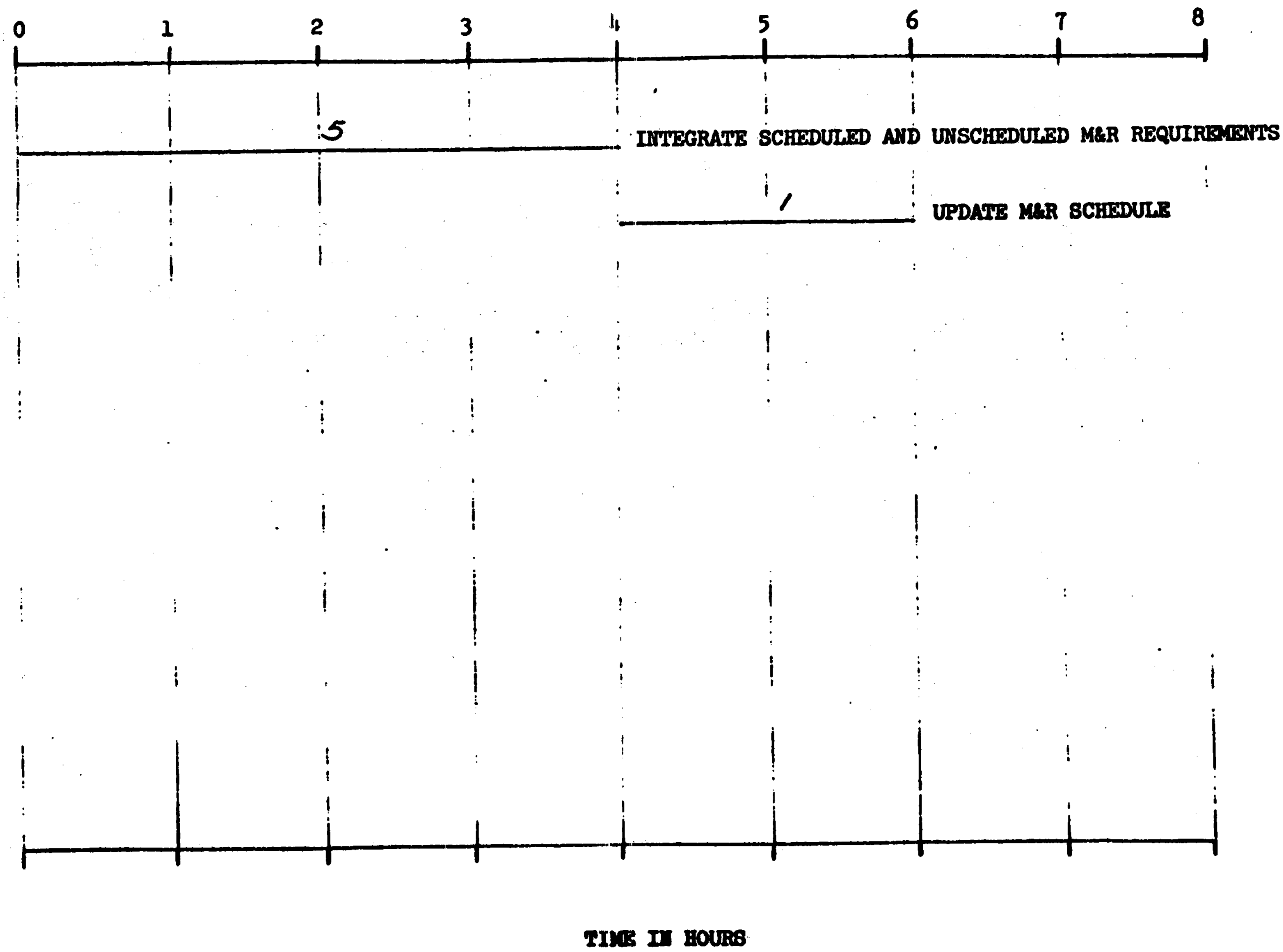
OPTION NUMBER	FUNCTION TITLE PREPARE PRELIMINARY M&R SCHEDULE	FLOW BLOCK NO. 1.1.1



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
	ANALYZE T/M FOR UNSCHEDULE M&R	1.1.2



OPTION NUMBER	FUNCTION TITLE UPDATE M&R SCHEDULE	FLOW BLOCK NO. 1.1.3



OPTION NUMBER	FUNCTION TITLE	RECEIVE TUG AT TPF/PPF	FLOW BLOCK NO.	1.1.4

0 1 2 3 4 5 6 7 8

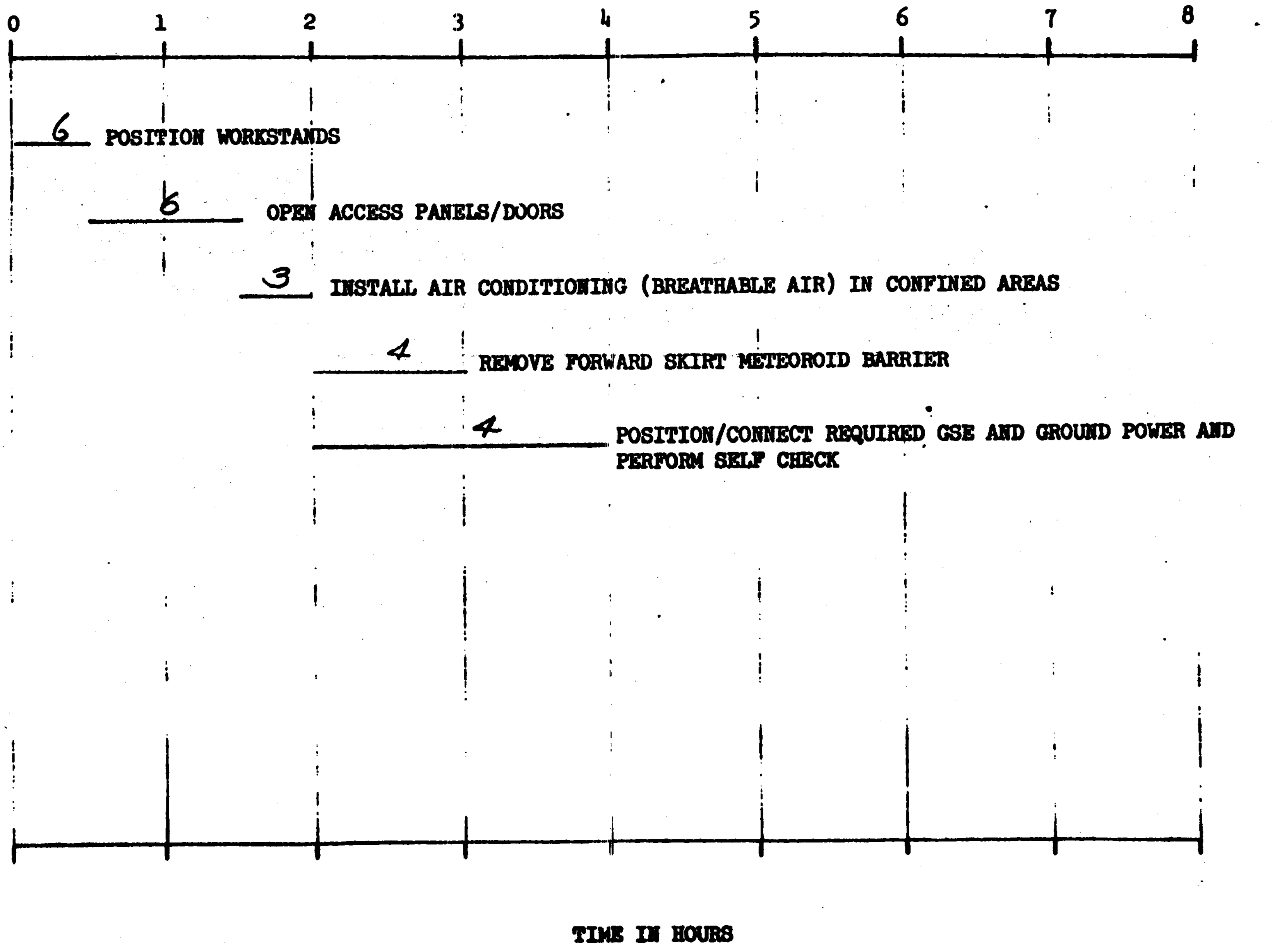
3 POSITION TUG (ON TRANSPORTER) AND ESTABLISH AND VERIFY ELECTRICAL GROUND

3 REMOVE PROTECTIVE COVERS

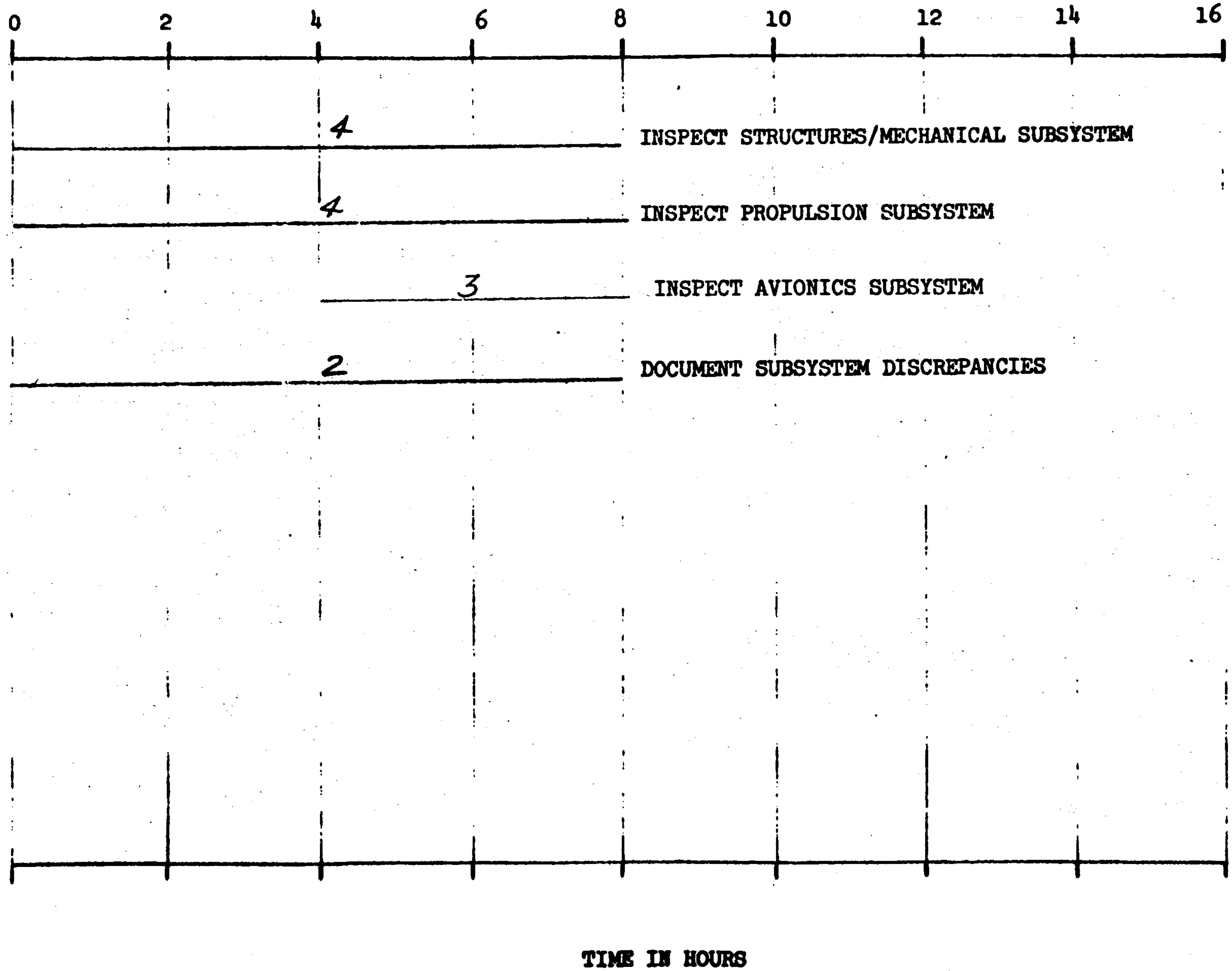
2 PERFORM SAFETY CHECK

TIME IN HOURS

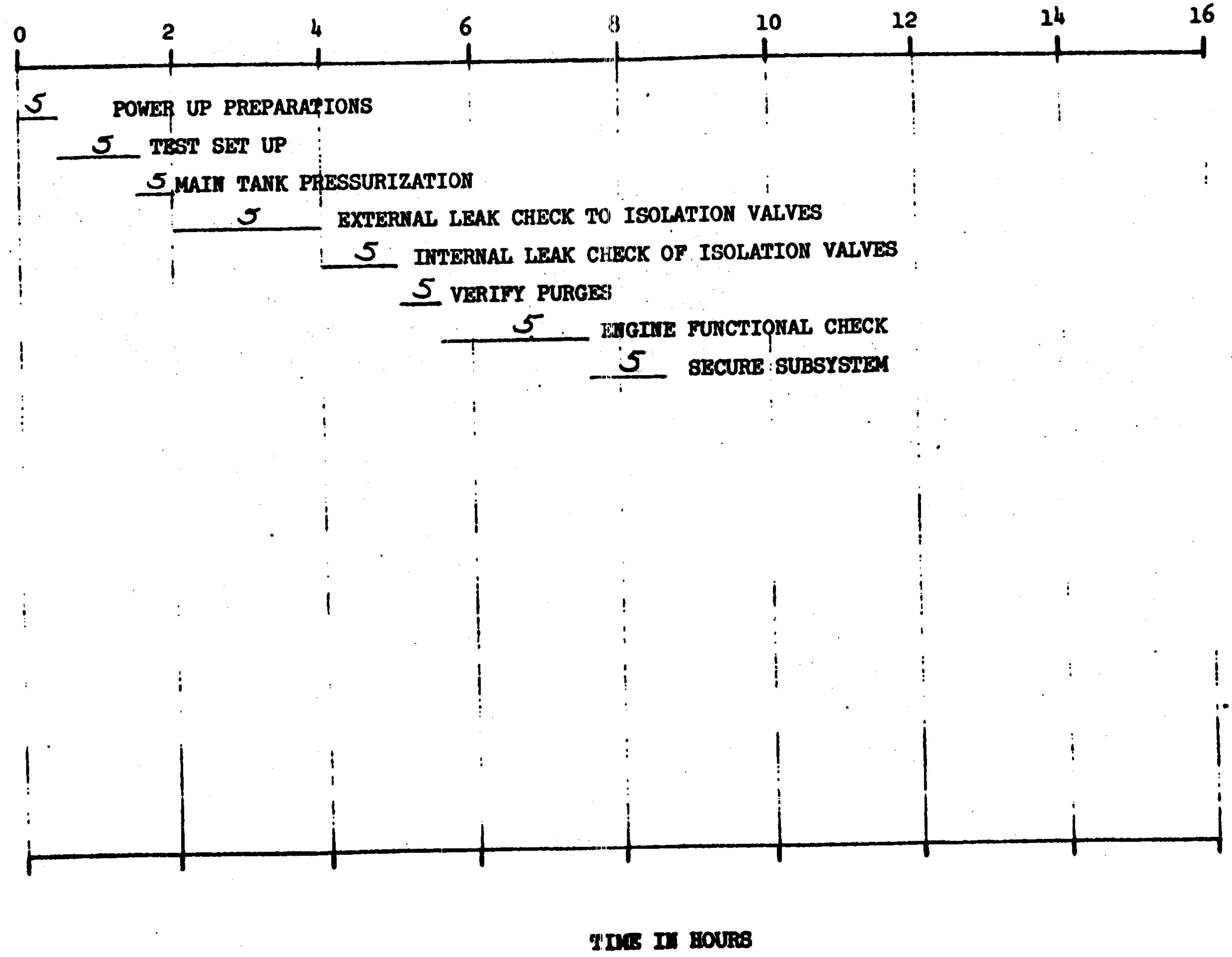
OPTION NUMBER	FUNCTION TITLE	PREPARE FOR INSPECTION AND C/O	FLOW BLOCK NO.	1.1.5



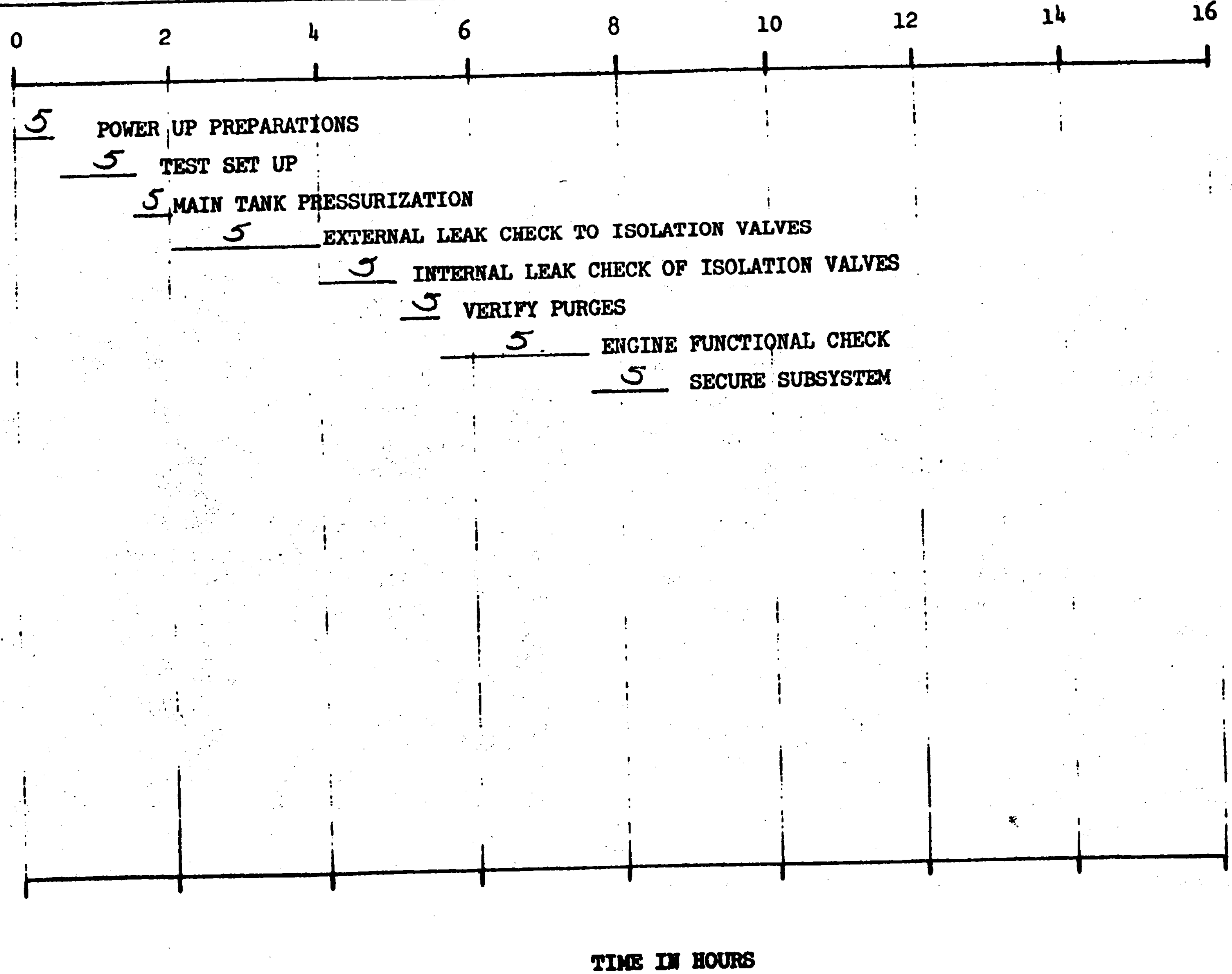
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
	PERFORM POST FLIGHT RECEIVING INSPECTION	1.1.6



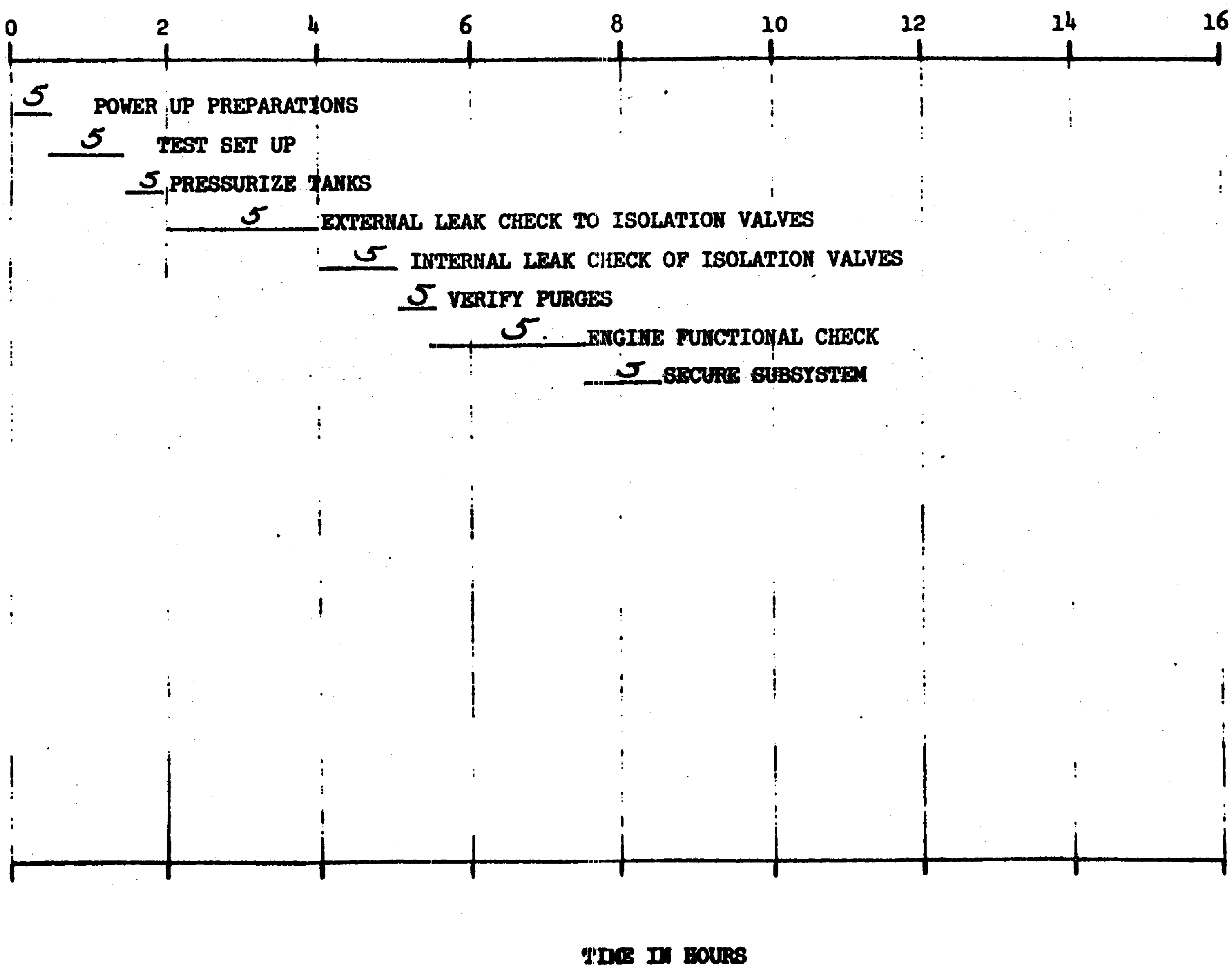
OPTION NUMBER	FUNCTION POST FLIGHT CHECKOUT - MAIN PROPULSION TITLE PRESSURIZATION - AMBIENT HELIUM & GH_2 BLEED	FLOW BLOCK NO. 1.1.7.1



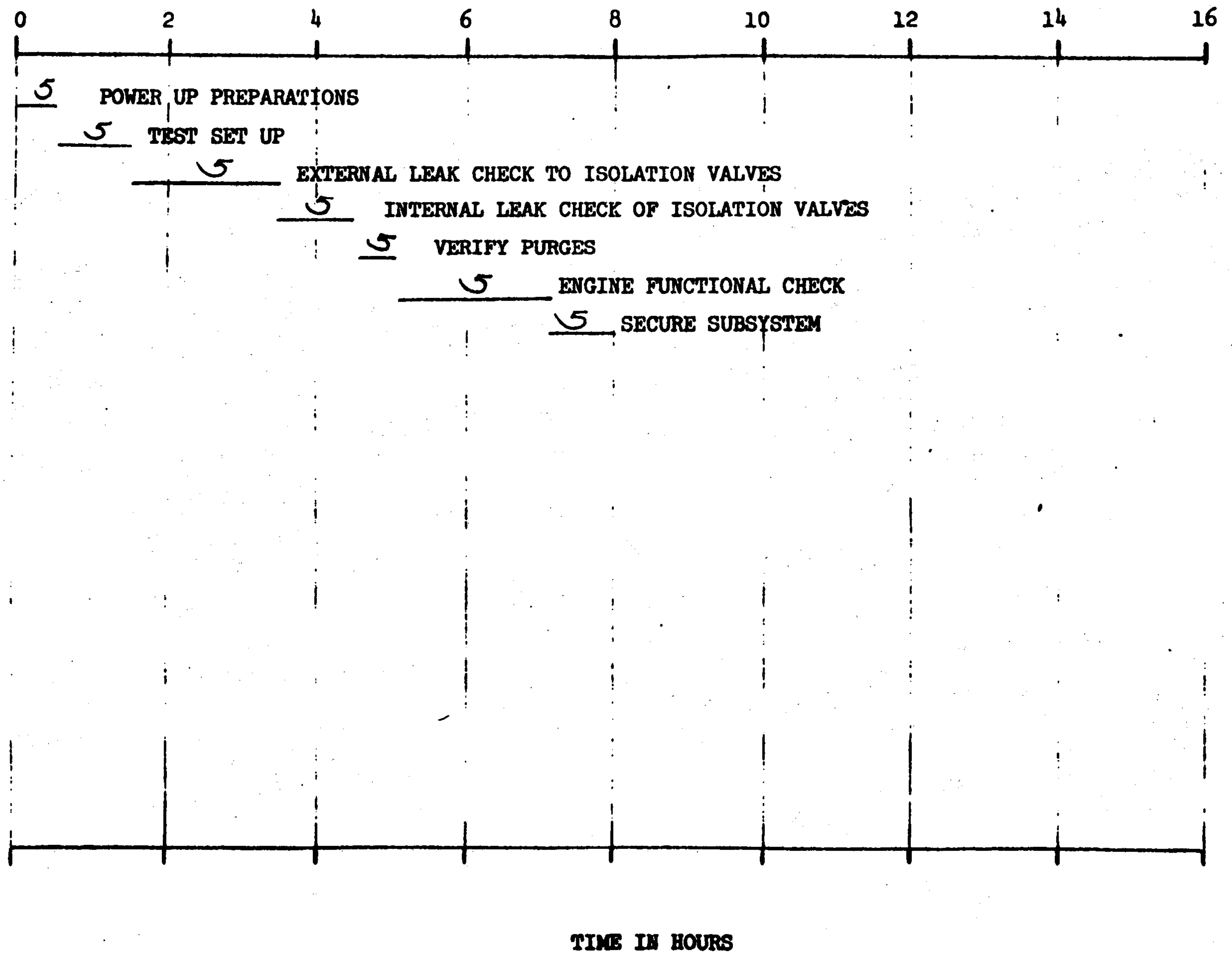
OPTION NUMBER	FUNCTION POST FLIGHT CHECKOUT - MAIN PROPULSION TITLE PRESSURIZATION - COLD HELIUM & GH_2 BLEED	FLOW BLOCK NO. 1.1.7.2



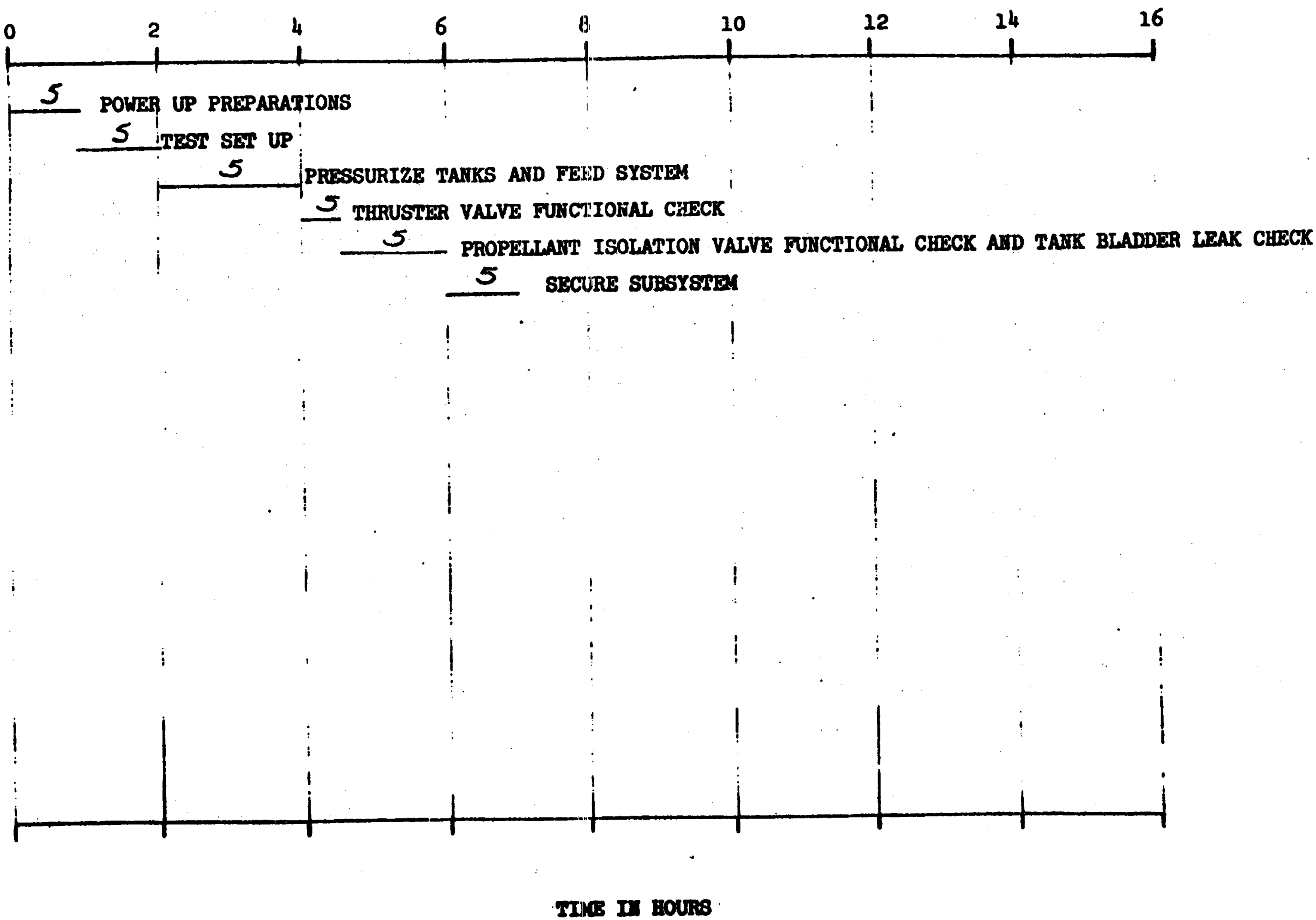
OPTION NUMBER	FUNCTION TITLE POST FLIGHT CHECKOUT - MAIN PROPULSION PRESSURIZATION - AUTOGENOUS (ALL ENGINE BLEED)	FLOW BLOCK NO. 1.1.7.3



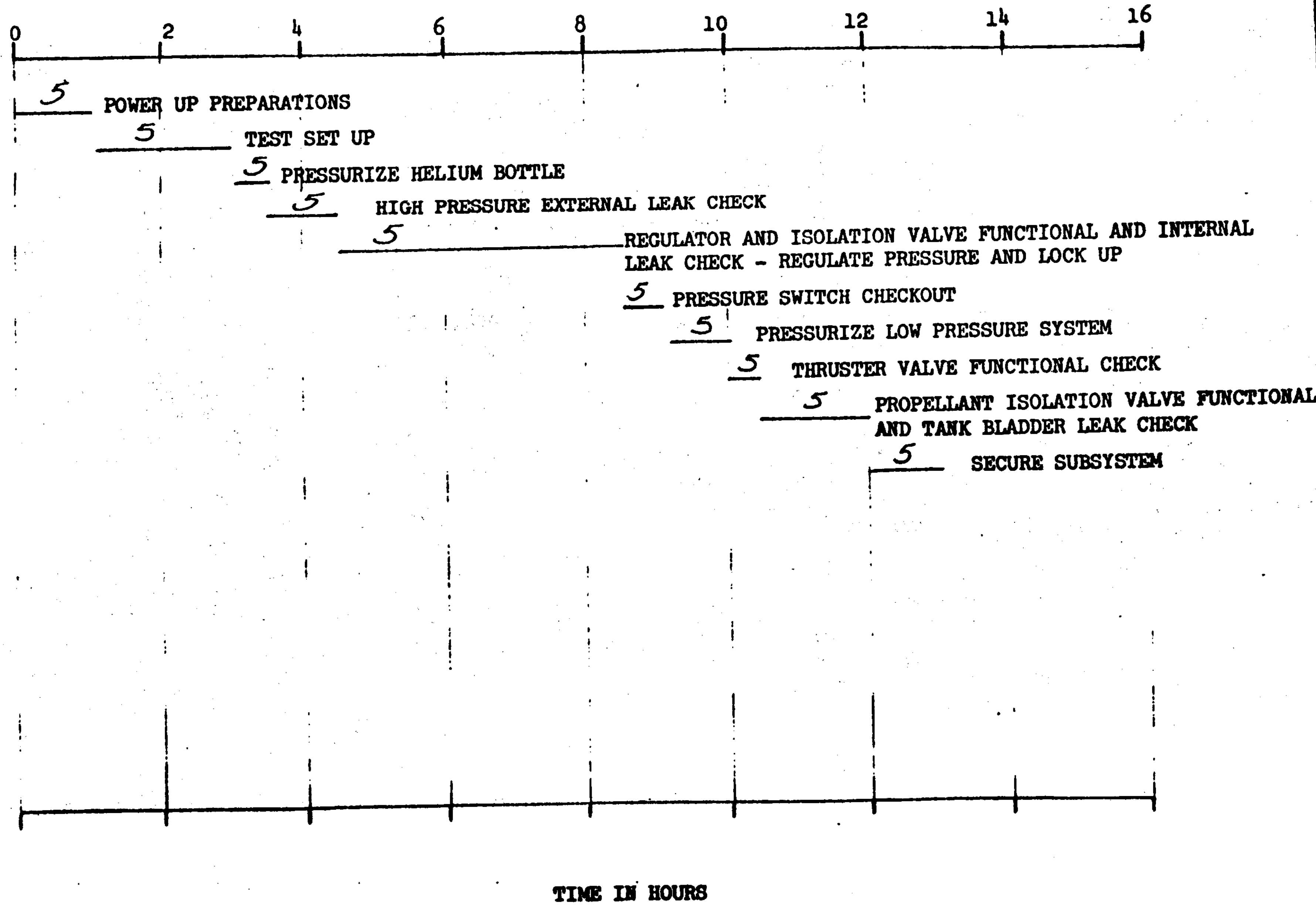
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
	POST FLIGHT CHECKOUT - MAIN PROPULSION ZERO NPSH	1.1.7.4



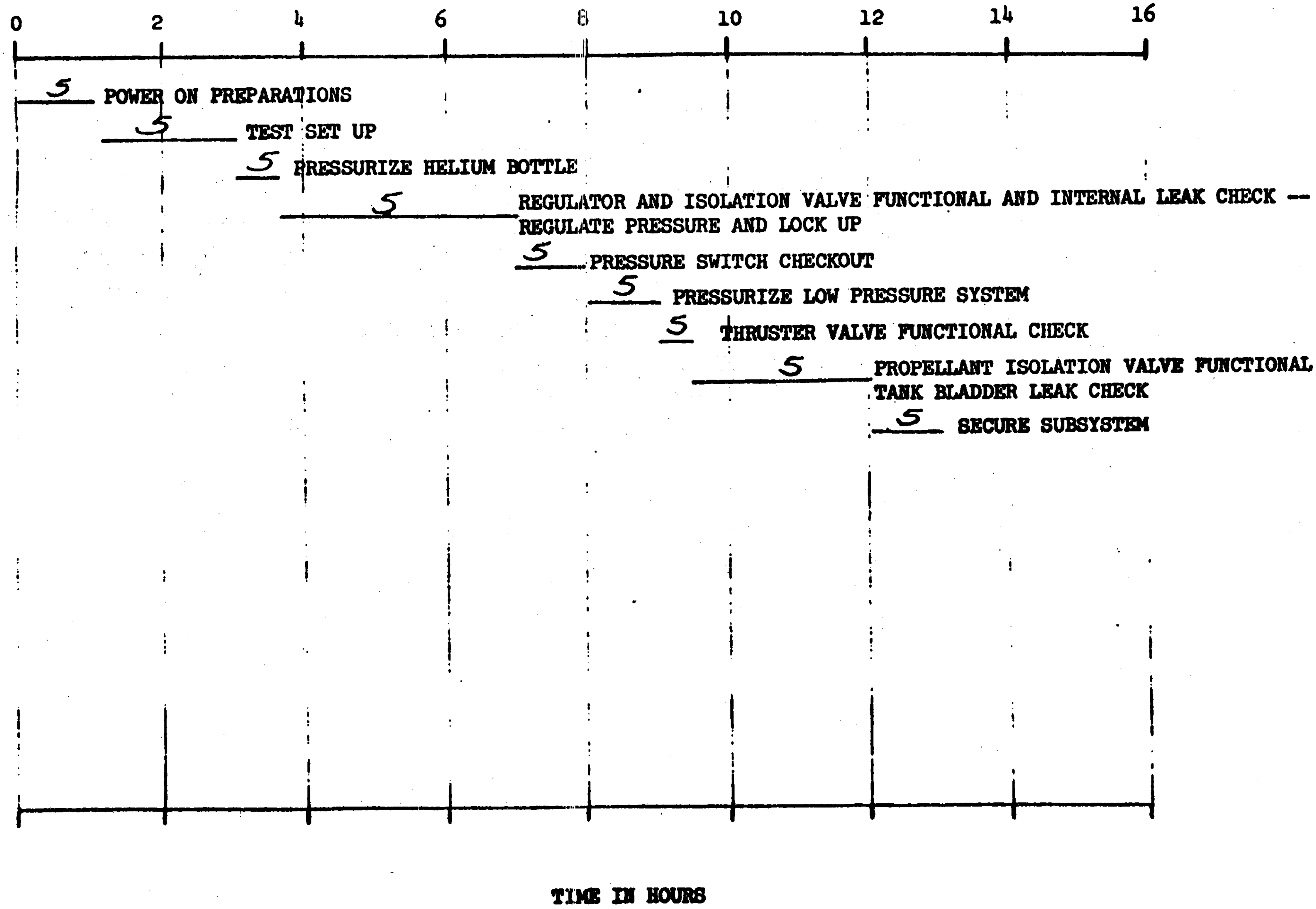
OPTION NUMBER	FUNCTION TITLE POST FLIGHT CHECKOUT - APS SUBSYSTEM - MONOPROPELLANT - BLOWDOWN	FLOW BLOCK NO. 1.1.7.5



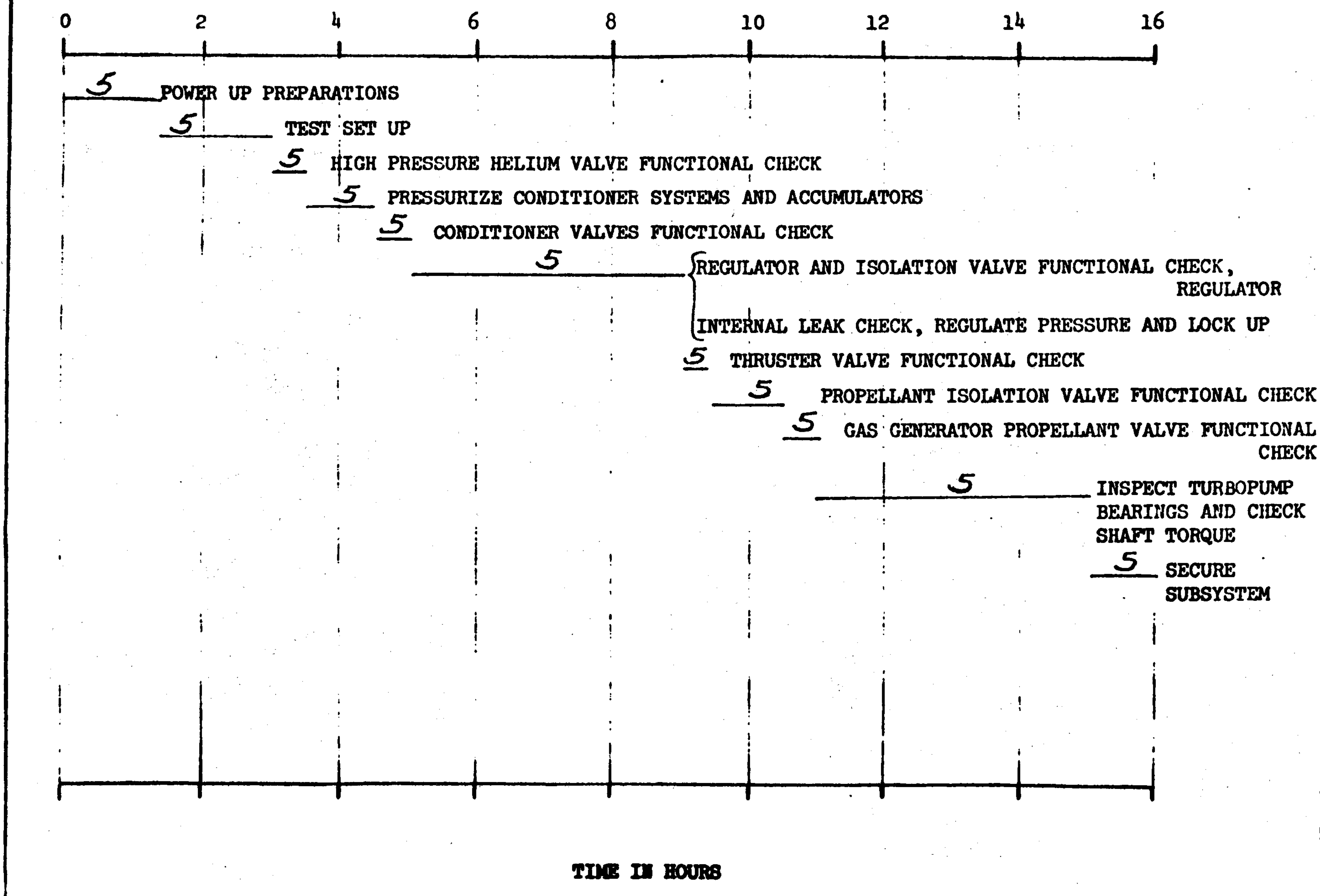
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
	POST FLIGHT CHECKOUT - APS SUBSYSTEM MONOPROPELLANT - PRESSURIZED	1.1.7.6



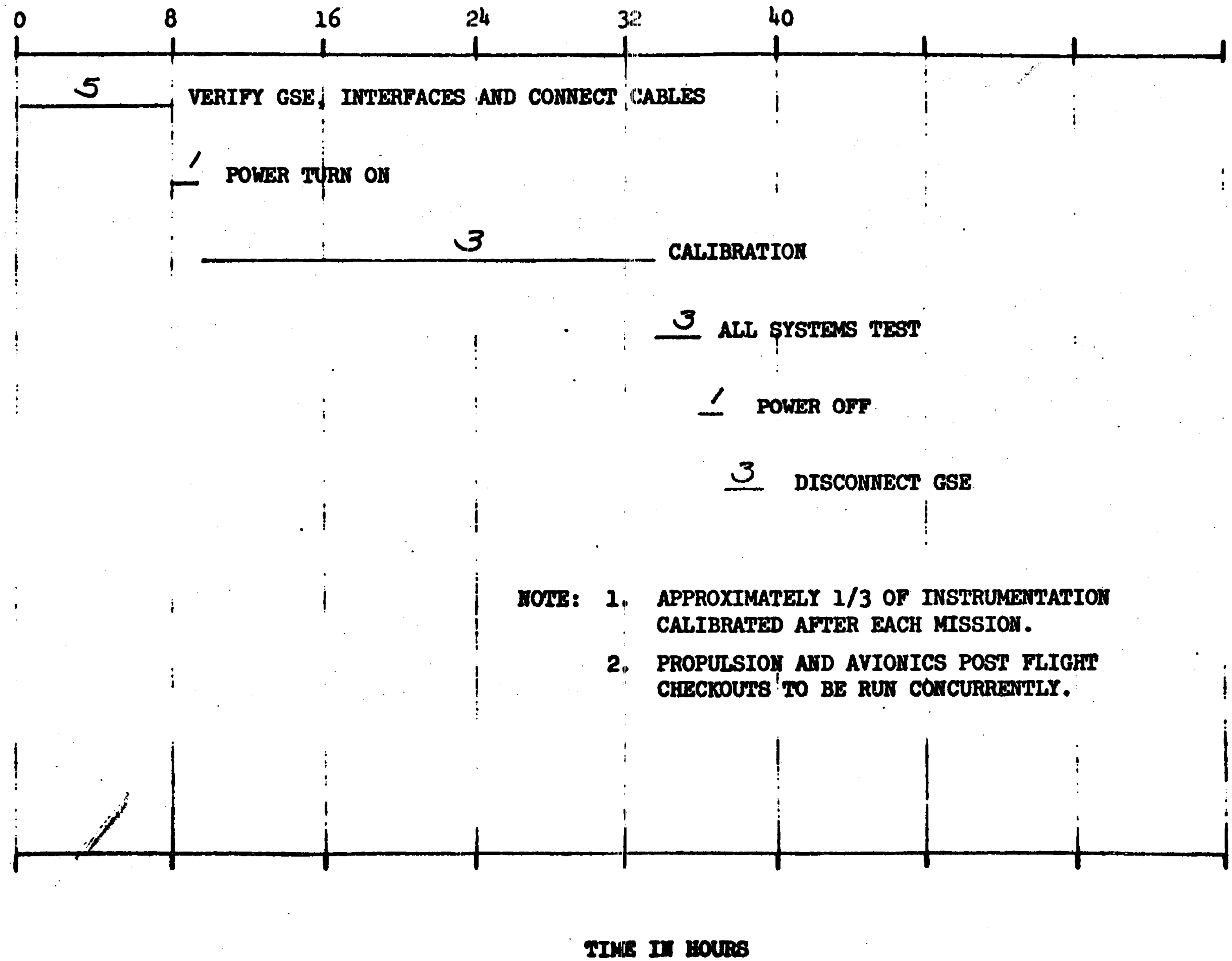
OPTION NUMBER	FUNCTION TITLE	POST FLIGHT CHECKOUT - APS SUBSYSTEM - BIPROPELLANT	FLOW BLOCK NO.	1.1.7.7



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
	POST FLIGHT CHECKOUT - APS SUBSYSTEM - CRYOGENIC	1.1.7.8



OPTION NUMBER	FUNCTION TITLE	POST FLIGHT CHECKOUT - AVIONICS	FLOW BLOCK NO.	1.1.7.9



NOTE: 1. APPROXIMATELY 1/3 OF INSTRUMENTATION CALIBRATED AFTER EACH MISSION.

2. PROPULSION AND AVIONICS POST FLIGHT CHECKOUTS TO BE RUN CONCURRENTLY.

OPTION NUMBER	FUNCTION POST STORAGE CHECKOUT - MAIN PROPULSION TITLE PRESSURIZATION - AMBIENT HELIUM AND GH_2 BLEED	FLOW BLOCK NO. 1.1.8.1

0 4 8 12 16 20 24 28 32

5 POWER UP PREPARATIONS

5 TEST SET UP

5 PNEUMATIC SYSTEM PRESSURIZATION

5 PNEUMATIC LEAK CHECK, ACM AND REGULATOR FUNCTIONAL CHECK

5 MAIN TANK PRESSURIZATION

5 EXTERNAL LEAK CHECK TO ISOLATION VALVES

5 INTERNAL LEAK CHECK OF ISOLATION VALVES

5 EXERCISE VALVES PLUS LEAK CHECK

5 PRESSURIZE SYSTEM PLUS LEAK AND FUNCTIONAL CHECK

5 VERIFY PURGES

5 CALIBRATE TRANSDUCERS

5 ENGINE FUNCTIONAL CHECK

5 SECURE SUBSYSTEM

TIME IN HOURS

OPTION NUMBER	FUNCTION POST STORAGE CHECKOUT - MAIN PROPULSION TITLE PRESSURIZATION - COLD HELIUM AND GH_2 BLEED	FLOW BLOCK NO. 1.1.8.2

0 8 16 24 32 40 48 56 64

5 POWER UP PREPARATIONS

5 TEST SET UP

5 PNEUMATIC SYSTEM PRESSURIZATION

5 PNEUMATIC LEAK CHECK, ACM AND REGULATOR FUNCTIONAL CHECK

5 MAIN TANK PRESSURIZATION

5 EXTERNAL LEAK CHECK TO ISOLATION VALVES

5 INTERNAL LEAK CHECK OF ISOLATION VALVES

5 EXERCISE VALVES PLUS LEAK CHECK

5 PRESSURIZE SYSTEM PLUS LEAK AND FUNCTIONAL CHECK

5 VERIFY PURGES

5 CALIBRATE TRANSDUCERS

5 ENGINE FUNCTIONAL CHECK

5 SECURE SUBSYSTEM

TIME IN HOURS

OPTION NUMBER	FUNCTION POST STORAGE CHECKOUT - MAIN PROPULSION TITLE PRESSURIZATION - AUTOGENOUS (ALL ENGINE BLEED)	FLOW BLOCK NO. 1.1.8.3

0 4 8 12 16 20 24 28 32

5 POWER UP PREPARATIONS

5 TEST SET UP

5 PNEUMATIC SYSTEM PRESSURIZATION

5 PNEUMATIC LEAK CHECK, ACM AND REGULATOR FUNCTIONAL CHECK

5 MAIN TANK PRESSURIZATION

5 EXTERNAL LEAK CHECK TO ISOLATION VALVES

5 INTERNAL LEAK CHECK OF ISOLATION VALVES

5 EXERCISE VALVES PLUS LEAK CHECK

5 PRESSURIZE SYSTEM PLUS LEAK AND FUNCTIONAL CHECK

5 VERIFY PURGES

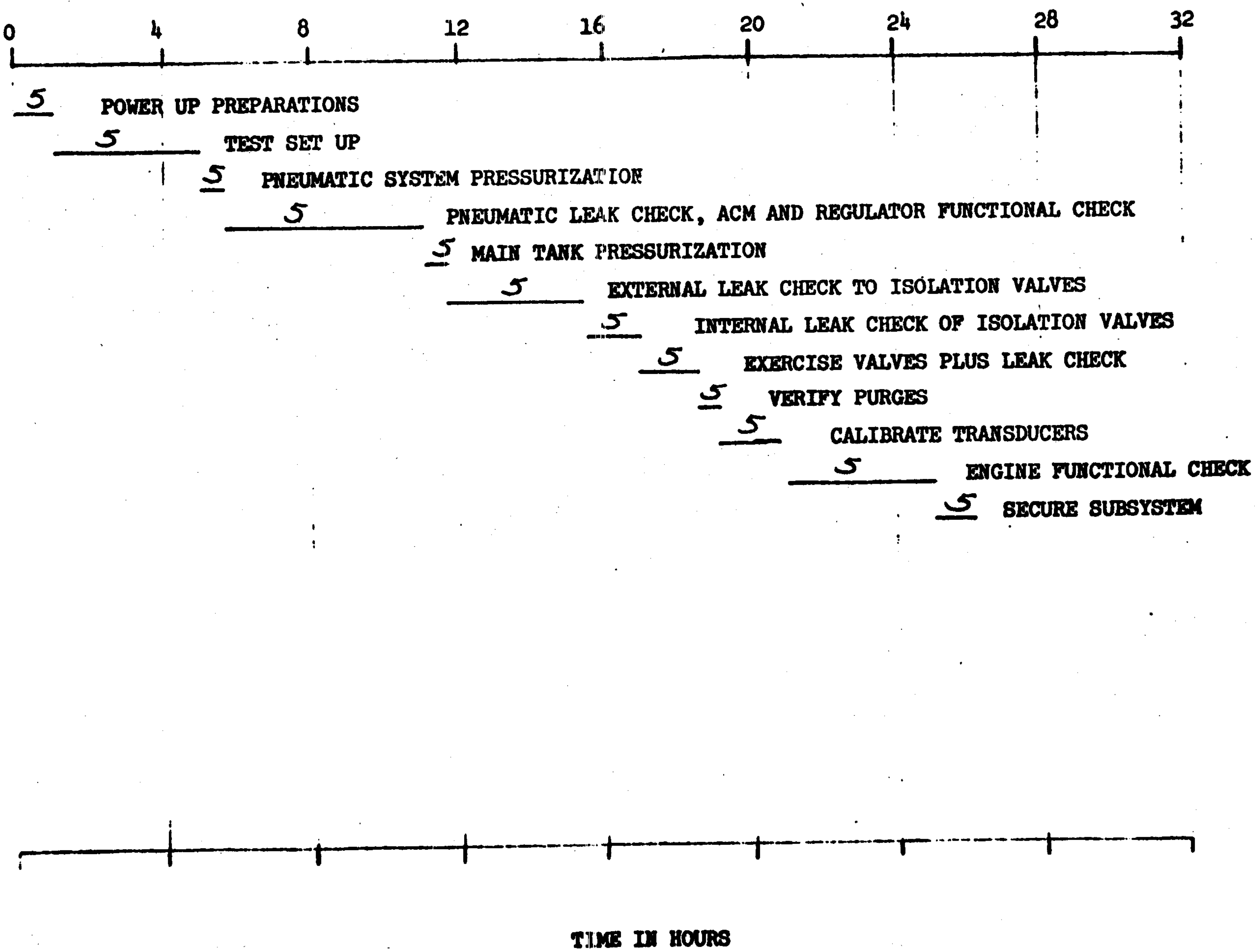
5 CALIBRATE TRANSDUCERS

5 ENGINE FUNCTIONAL CHECK

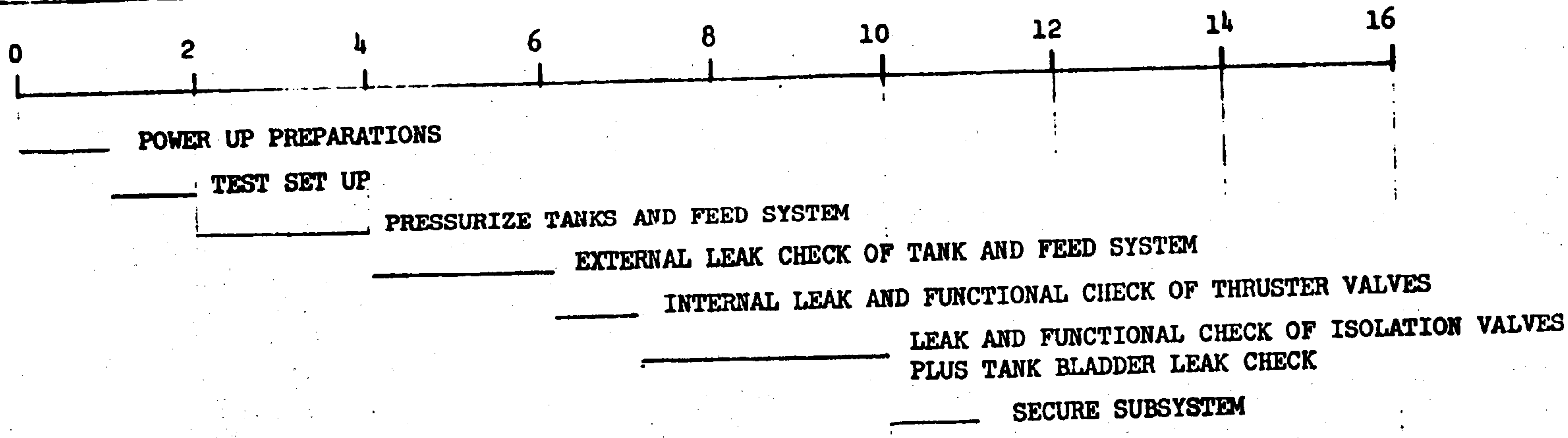
5 SECURE SUBSYSTEM

TIME IN HOURS

OPTION NUMBER	FUNCTION TITLE	POST STORAGE CHECKOUT - MAIN PROPULSION ZERO NPSH	FLOW BLOCK NO.	1.1.8.4



OPTION NUMBER	FUNCTION TITLE POST STORAGE CHECKOUT - APS SUBSYSTEM MONOPROPELLANT - BLOWDOWN	FLOW BLOCK NO. 1.1.8.5



NOTE: THIS ACTIVITY OCCURS AFTER THE DELIVERY OF EACH TUG FROM STORAGE

TIME IN HOURS

OPTION NUMBER	FUNCTION TITLE	POST STORAGE CHECKOUT - APS SUBSYSTEM MONO PROPELLANT -PRESSURIZED	FLOW BLOCK NO.	1.1.8.6

0 4 8 12 16 20 24 28 32

5 POWER UP PREPARATIONS

5 TEST SET UP

5 PRESSURIZE HELIUM BOTTLE

5 HIGH PRESSURE EXTERNAL LEAK CHECK

5 REGULATOR AND ISOLATION VALVE FUNCTIONAL AND INTERNAL LEAK CHECK - REGULATE PRESSURE AND LOCK UP

5 PRESSURE SWITCH CHECKOUT

5 PRESSURIZE LOW PRESSURE SYSTEM

5 LOW PRESSURE SYSTEM EXTERNAL LEAK CHECK

5 THRUSTER VALVE INTERNAL LEAK AND FUNCTIONAL CHECK

5 PROPELLANT ISOLATION VALVE LEAK AND FUNCTIONAL CHECK PLUS TANK BLADDER LEAK CHECK

5 SECURE SUBSYSTEM

NOTE: THIS ACTIVITY OCCURS AFTER DELIVERY OF EACH TUG FROM STORAGE

TIME IN HOURS

OPTION NUMBER	FUNCTION TITLE POST STORAGE CHECKOUT - APS SUBSYSTEM BIPROPELLANT	FLOW BLOCK NO. 1.1.8.7

0 4 8 12 16 20 24 28 32

5 POWER UP PREPARATIONS

5 TEST SET UP

5 PRESSURIZE HELIUM BOTTLE

5 HIGH PRESSURE EXTERNAL LEAK CHECK

5 REGULATOR AND ISOLATION VALVE FUNCTIONAL AND INTERNAL LEAK CHECK - REGULATE PRESSURE AND LOCK UP

5 PRESSURE SWITCH CHECKOUT

5 PRESSURIZE LOW PRESSURE SYSTEM

5 LOW PRESSURE SYSTEM EXTERNAL LEAK CHECK

5 THRUSTER VALVE INTERNAL LEAK CHECK

5 PROPELLANT ISOLATION VALVE LEAK AND FUNCTIONAL CHECK PLUS TANK BLADDER LEAK CHECK

5 SECURE SUBSYSTEM

NOTE: THIS ACTIVITY OCCURS AFTER DELIVERY OF EACH TUG FROM STORAGE

TIME IN HOURS

OPTION NUMBER	FUNCTION TITLE POST STORAGE CHECKOUT - APS SUBSYSTEM CRYOGENIC	FLOW BLOCK NO. 1.1.8.8

0 8 16 24 32 40 48 56 64

5 POWER UP PREPARATIONS

5 TEST SET UP

5 PRESSURIZE HELIUM BOTTLE

5 HIGH PRESSURE EXTERNAL LEAK

5 HIGH PRESSURE HELIUM VALVE FUNCTIONAL AND INTERNAL LEAK CHECK

5 EXTERNAL LEAK CHECK OF TANKS

5 REVERSE FLOW LEAK CHECK OF CHECK VALVES

5 PRESSURIZE CONDITIONER SYSTEM

5 INTERNAL LEAK AND FUNCTIONAL CHECK OF CONDITIONER VALVES

5 PRESSURIZE ACCUMULATORS

5 REGULATOR AND ISOLATION VALVE FUNCTIONAL AND INTERNAL LEAK CHECK - REGULATE PRESSURE AND LOCK UP

5 THRUSTER VALVE INTERNAL LEAK CHECK

5 THRUSTER ISOLATION VALVE INTERNAL LEAK CHECK

5 EXTERNAL LEAK CHECK CONDITIONER AND PROPELLANT FEED SYSTEM AND PUMP SEALS

5 INTERNAL LEAK AND FUNCTIONAL CHECK OF GAS GENERATOR VALVES

5 EXTERNAL LEAK CHECK OF GAS GENERATORS

5 INSPECT TURBOPUMP BEARING AND CHECK SHAFT TORQUE

5 SECURE SUBSYSTEM

NOTE: THIS ACTIVITY OCCURS AFTER DELIVERY OF EACH TUG FROM STORAGE

TIME IN HOURS

OPTION NUMBER	FUNCTION TITLE PERFORM POST STORAGE C/O - AVIONICS	FLOW BLOCK NO. 1.1.8.9

0 8 16 72 80 88 96

5 VERIFY GSE, INTERFACES, AND CONNECT CABLES

1 POWER TURN ON

3 CALIBRATION

3 POWER DISTRIBUTION

3 COMMUNICATIONS TEST

3 APS TEST

3 ENGINE GIMBALLING

3 PROPULSION (PRESSURIZATION, PU, ENGINE ELECTRONICS)

3 THERMAL CONTROL

3 DATA MANAGEMENT

3 GUIDANCE AND NAVIGATION

3 ALL SYSTEMS TEST

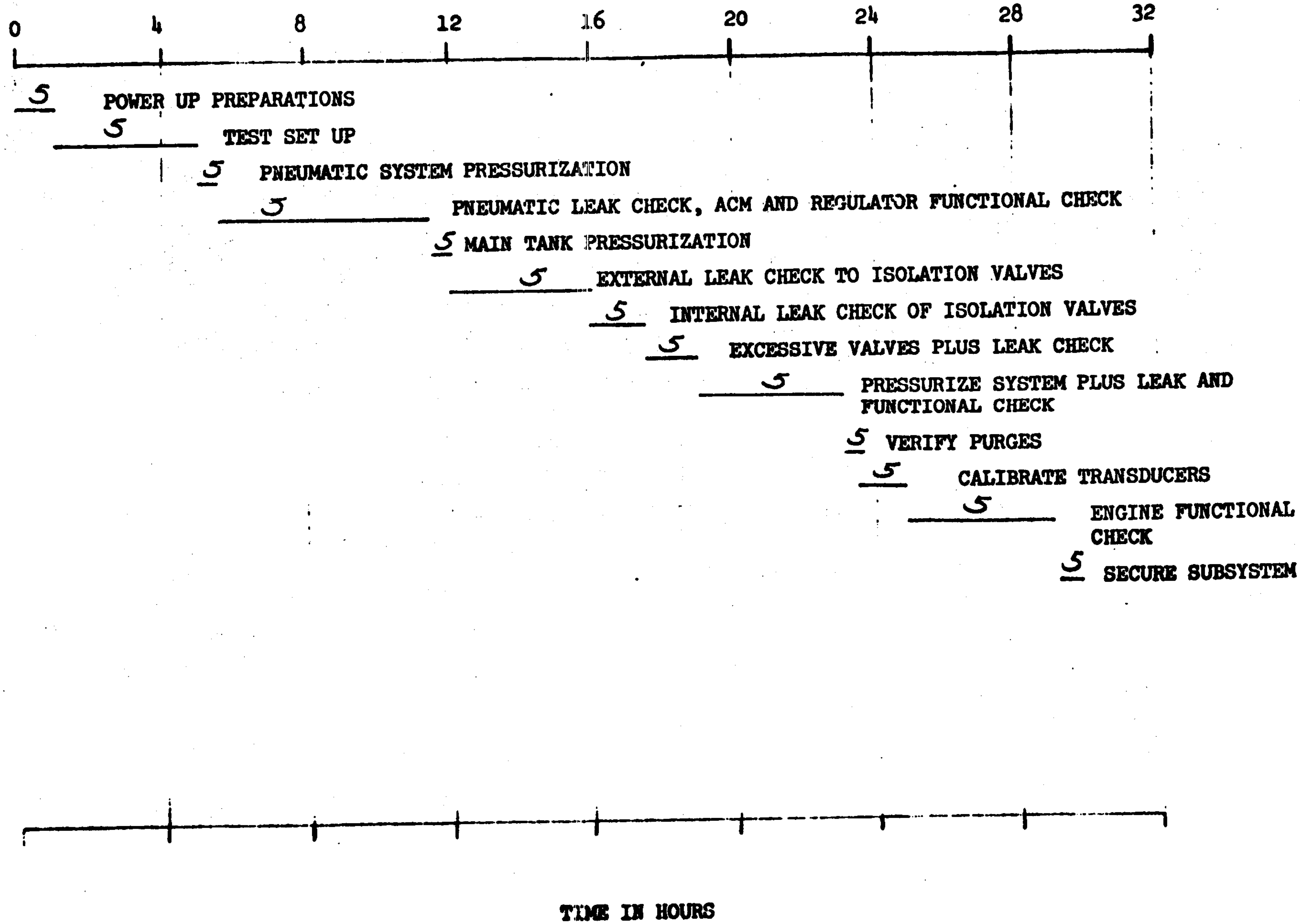
1 POWER OFF

3 DISCONNECT GSE

NOTE: THIS ACTIVITY OCCURS EACH TIME A TUG IS REMOVED FROM LONG TERM STORAGE

TIME IN HOURS

OPTION NUMBER	FUNCTION NEW TUG CHECKOUT - MAIN PROPULSION TITLE PRESSURIZATION - AMBIENT HELIUM AND GH_2 BLEED	FLOW BLOCK NO. 1.1.9.1



OPTION NUMBER	FUNCTION NEW TUG CHECKOUT - MAIN PROPULSION TITLE PRESSURIZATION - COLD HELIUM AND GH_2 BLEED	FLOW BLOCK NO. 1.1.9.2

0 8 16 24 32 40 48 56 64

5 POWER UP PREPARATIONS

5 TEST SET UP

5 PNEUMATIC SYSTEM PRESSURIZATION

5 PNEUMATIC LEAK CHECK, ACM AND REGULATOR FUNCTIONAL CHECK

5 MAIN TANK PRESSURIZATION

5 EXTERNAL LEAK CHECK TO ISOLATION VALVES

5 INTERNAL LEAK CHECK OF ISOLATION VALVES

5 EXERCISE VALVES PLUS LEAK CHECK

5 PRESSURIZE SYSTEM PLUS LEAK AND FUNCTIONAL CHECK

5 VERIFY PURGES

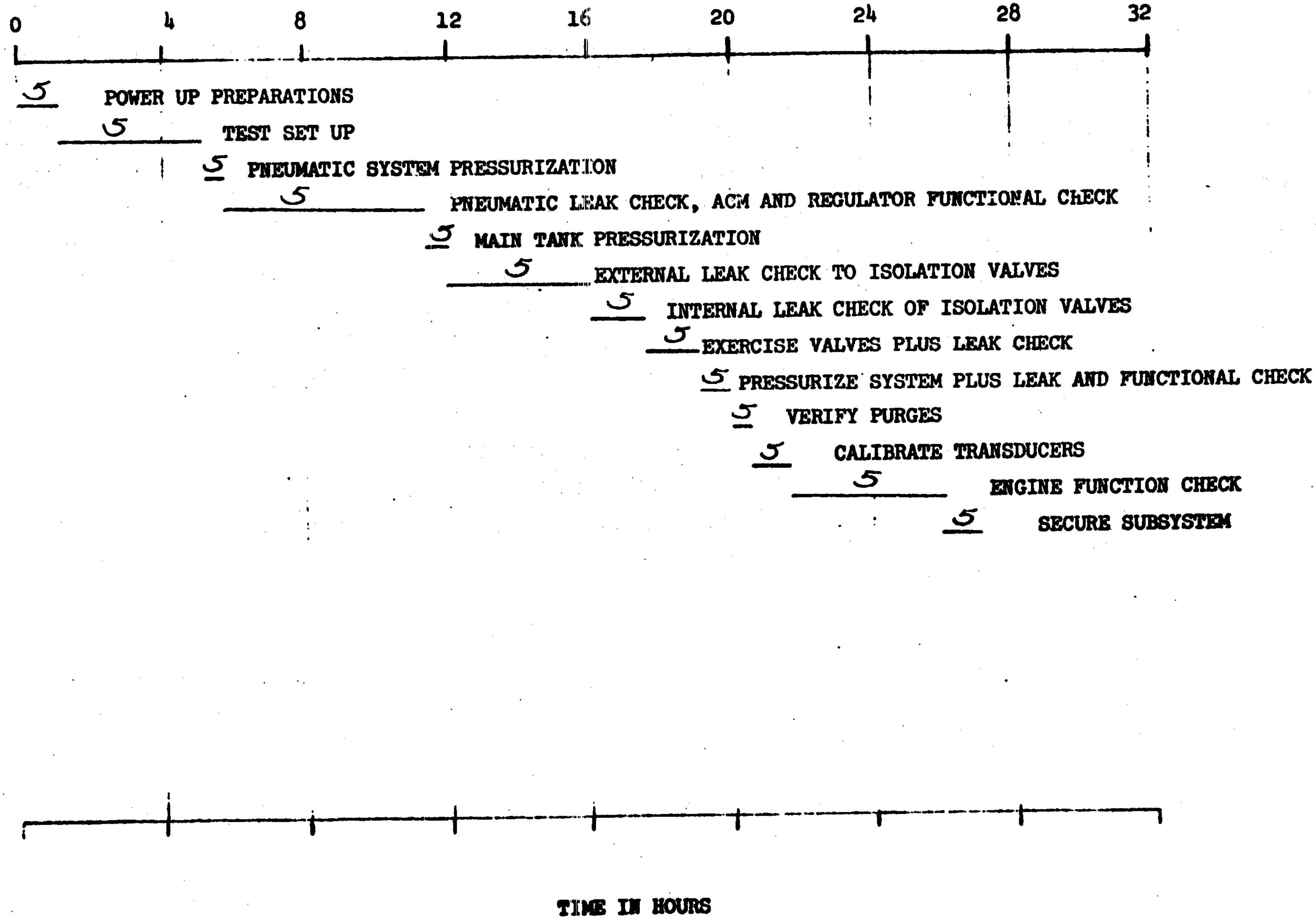
5 CALIBRATE TRANSDUCERS

5 ENGINE FUNCTIONAL CHECK

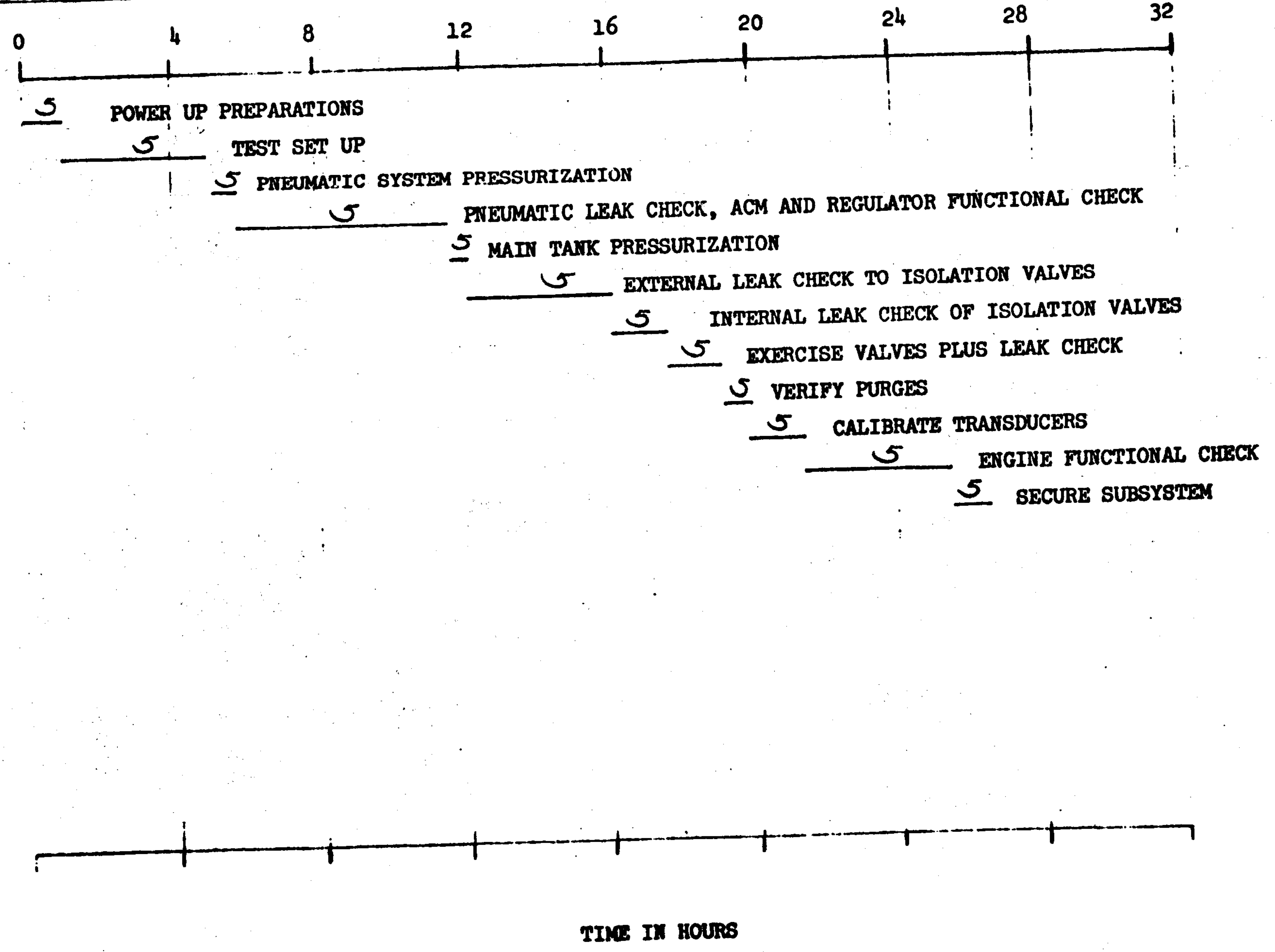
5 SECURE SUBSYSTEM

TIME IN HOURS

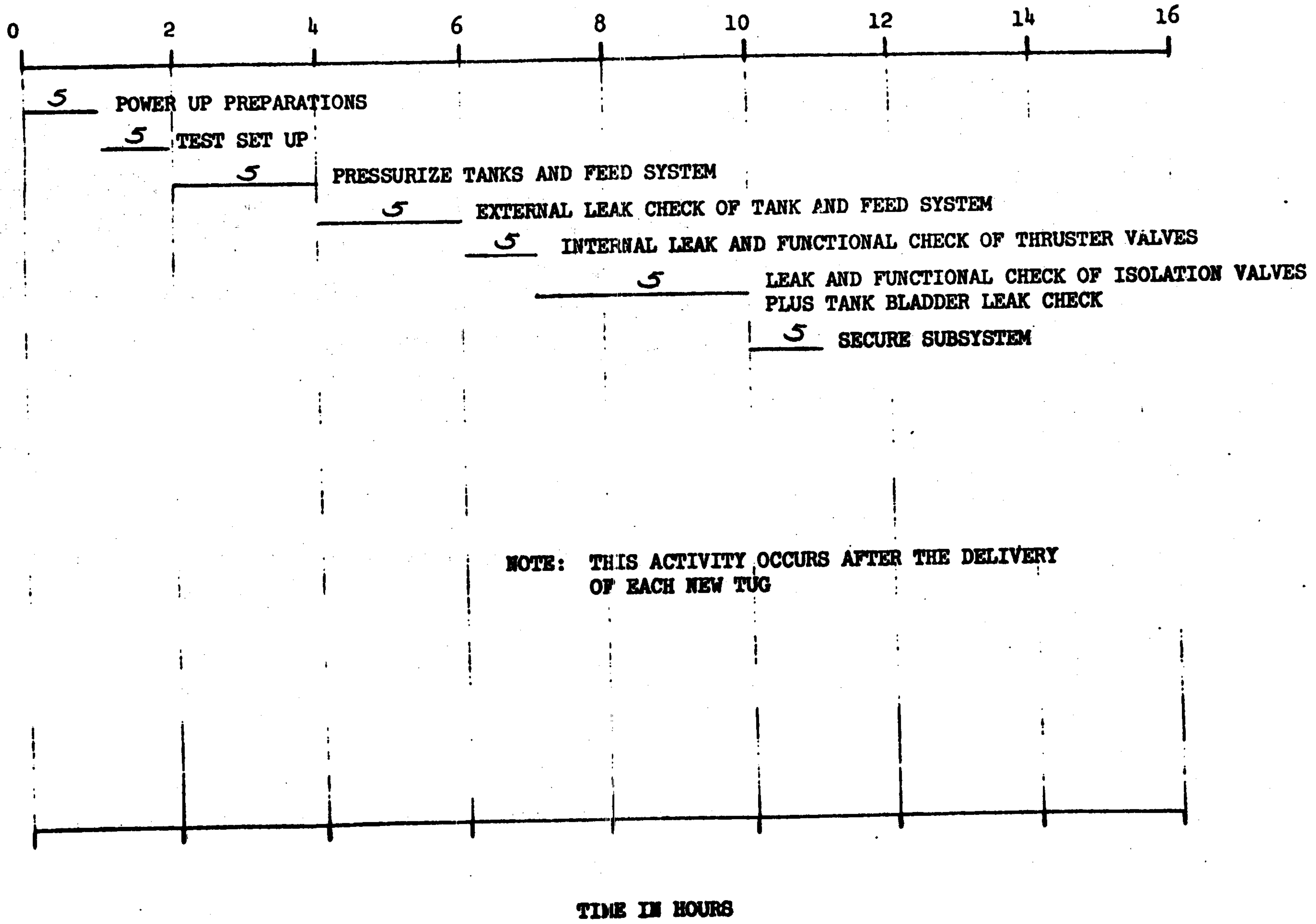
OPTION NUMBER	FUNCTION NEW TUG CHECKOUT - MAIN PROPULSION TITLE PRESSURIZATION - AUTOGENOUS (ALL ENGINE BLEED)	FLOW BLOCK NO. 1.1.9.3



OPTION NUMBER	FUNCTION TITLE: NEW TUG CHECKOUT - MAIN PROPULSION ZERO NPSH	FLOW BLOCK NO. 1.1.9.4



OPTION NUMBER	FUNCTION TITLE	NEW TUG CHECKOUT - APS SUBSYSTEM MONOPROPELLANT - BLOWDOWN	FLOW BLOCK NO.	1.1.9.5



NOTE: THIS ACTIVITY OCCURS AFTER THE DELIVERY OF EACH NEW TUG

OPTION NUMBER	FUNCTION TITLE: NEW TUG CHECKOUT - APS SUBSYSTEM MONOPROPELLANT - PRESSURIZED	FLOW BLOCK NO. 1.1.9.6

0 4 8 12 16 20 24 28 32

5 POWER UP PREPARATION

5 TEST SET UP

5 PRESSURIZE HELIUM BOTTLE

5 HIGH PRESSURE EXTERNAL LEAK CHECK

5 REGULATOR AND ISOLATION VALVE FUNCTIONAL AND INTERNAL LEAK CHECK - REGULATE PRESSURE AND LOCK UP

5 PRESSURE SWITCH CHECKOUT

5 PRESSURIZE LOW PRESSURE SYSTEM

5 LOW PRESSURE SYSTEM EXTERNAL LEAK CHECK

5 THRUSTER VALVE INTERNAL LEAK AND FUNCTIONAL CHECK

5 PROPELLANT ISOLATION VALVE LEAK AND FUNCTIONAL CHECK PLUS TANK BLADDER LEAK CHECK

5 SECURE SUBSYSTEM

NOTE: THIS ACTIVITY OCCURS AFTER DELIVERY OF EACH NEW TUG

TIME IN HOURS

OPTION NUMBER	FUNCTION TITLE NEW TUG CHECKOUT - APS SUBSYSTEM BIPROPELLANT	FLOW BLOCK NO. 1.1.9.7

0 4 8 12 16 20 24 28 32

5 POWER UP PREPARATIONS

5 TEST SET UP

5 PRESSURIZE HELIUM BOTTLE

5 HIGH PRESSURE EXTERNAL LEAK CHECK

5 REGULATOR AND ISOLATION VALVE FUNCTIONAL AND INTERNAL LEAK CHECK - REGULATE PRESSURE AND LOCK UP

5 PRESSURE SWITCH CHECKOUT

5 PRESSURIZE LOW PRESSURE SYSTEM

5 LOW PRESSURE SYSTEM EXTERNAL LEAK CHECK

5 THRUSTER VALVE INTERNAL LEAK CHECK

5 PROPELLANT ISOLATION VALVE LEAK AND FUNCTIONAL CHECK PLUS TANK BLADDER LEAK CHECK

5 SECURE SUBSYSTEM

NOTE: THIS ACTIVITY OCCURS AFTER DELIVERY OF EACH NEW TUG

TIME IN HOURS

OPTION NUMBER	FUNCTION TITLE NEW TUG CHECKOUT - APS SUBSYSTEM CRYOGENIC	FLOW BLOCK NO. 1.1.9.8

0 8 16 24 32 40 48 56 64

5 POWER UP PREPARATIONS

5 TEST SET UP

5 PRESSURIZE HELIUM BOTTLES

5 HIGH PRESSURE EXTERNAL LEAKS

5 HIGH PRESSURE HELIUM VALVE FUNCTIONAL AND INTERNAL LEAK CHECK

5 EXTERNAL LEAK CHECK OF TANKS

5 REVERSE FLOW LEAK CHECK OF CHECK VALVES

5 PRESSURIZE CONDITIONER SYSTEM

5 INTERNAL LEAK AND FUNCTIONAL CHECK OF CONDITIONER VALVES

5 PRESSURIZE ACCUMULATOR

5 REGULATOR AND ISOLATION VALVE FUNCTIONAL AND INTERNAL LEAK CHECK - REGULATE PRESSURE AND LOCK UP

5 THRUSTER VALVE INTERNAL LEAK CHECK

5 THRUSTER ISOLATION VALVE INTERNAL LEAK CHECK

5 EXTERNAL LEAK CHECK CONDITIONERS AND PROPELLANT FEED SYSTEM AND PUMP SEALS

5 INTERNAL LEAK AND FUNCTIONAL CHECK OF GAS GENERATOR VALVES

5 EXTERNAL LEAK CHECK OF GAS GENERATORS

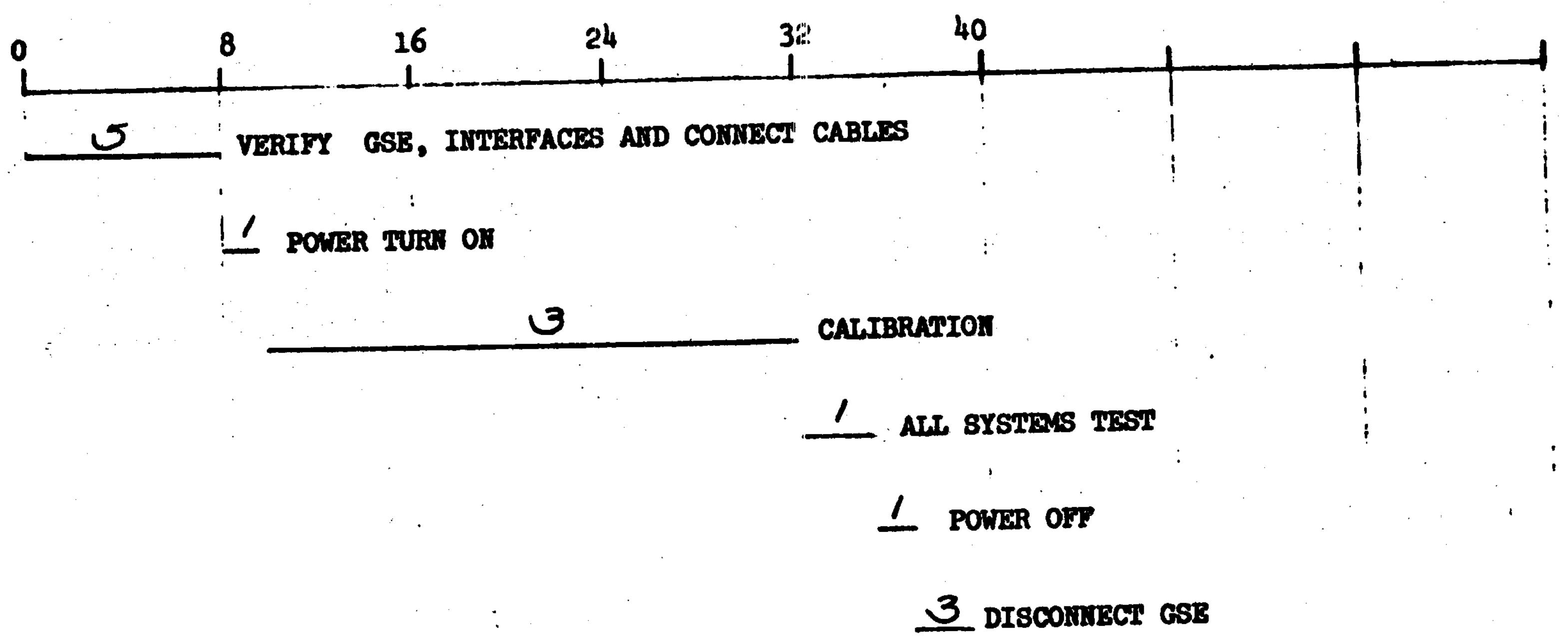
5 INSPECT TURBOPUMP BEARINGS AND CHECK SHAFT TORQUE

5 SECURE SUBSYSTEM

NOTE: THIS ACTIVITY OCCURS AFTER DELIVERY OF EACH NEW TUG

TIME IN HOURS

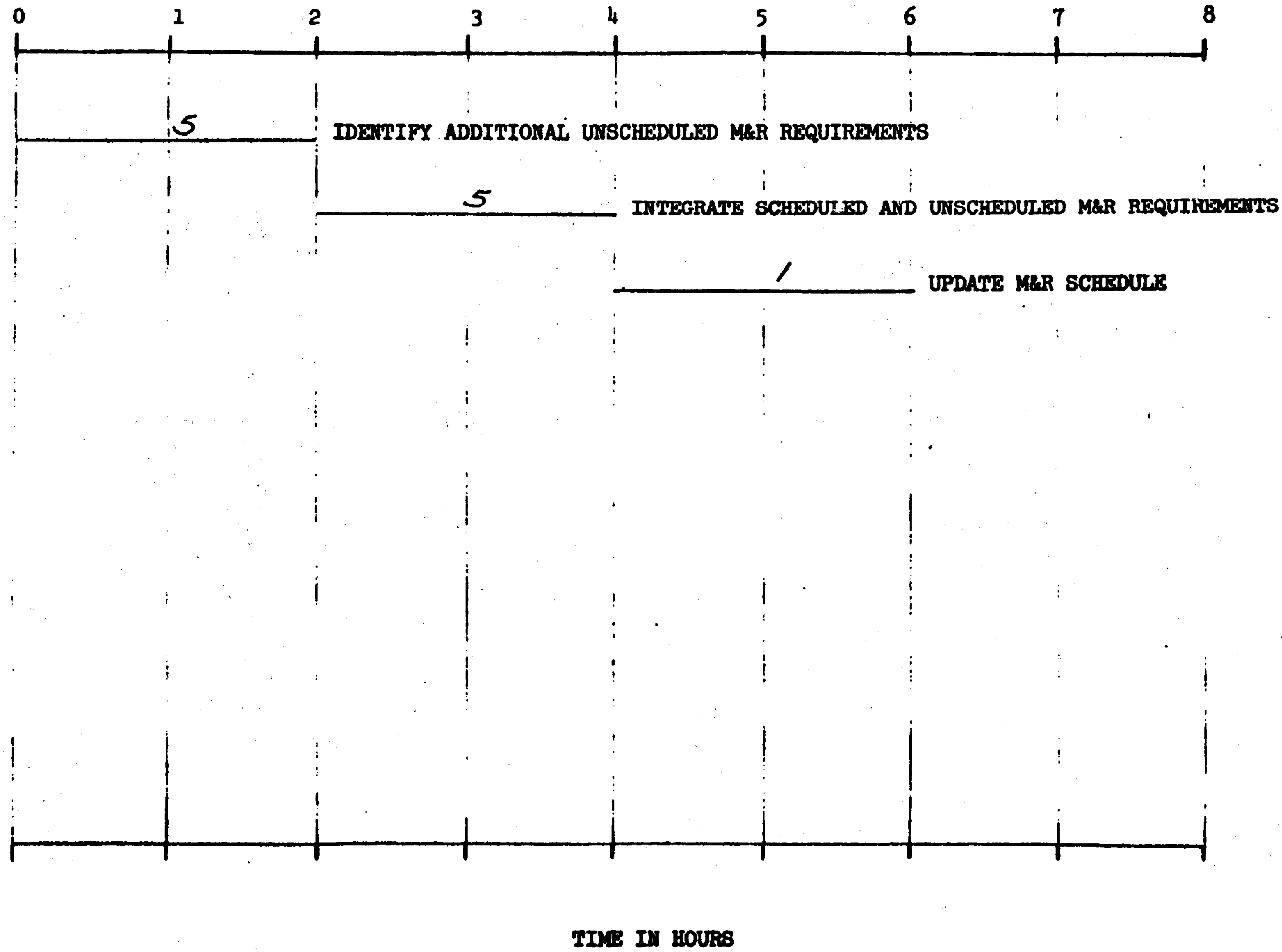
OPTION NUMBER	FUNCTION TITLE NEW TUG CHECKOUT - AVIONICS	FLOW BLOCK NO. 1.1.9.9



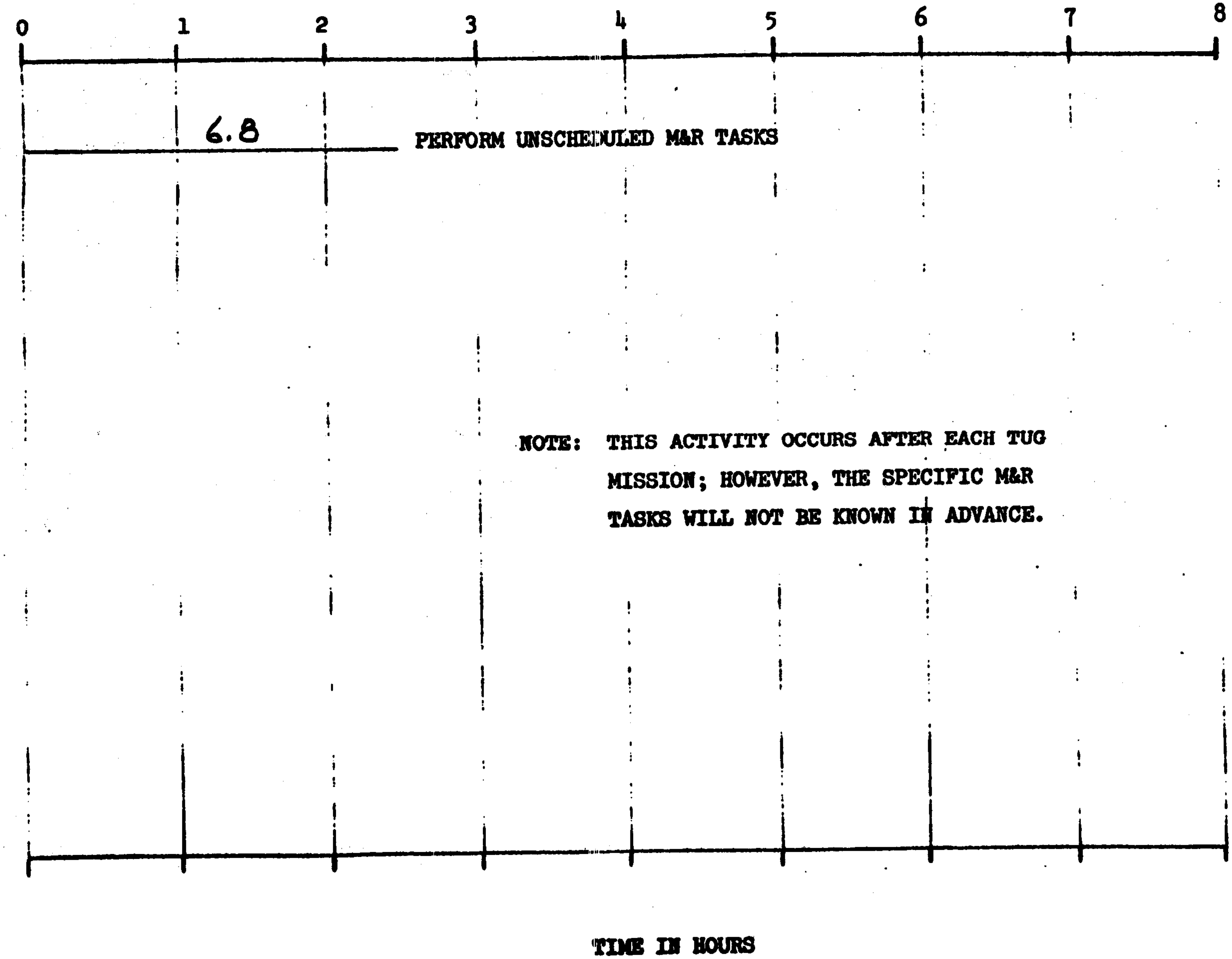
NOTES:
1. THIS ACTIVITY OCCURS AFTER EACH NEW TUG DELIVERY
2. APPROX. 1/3 OF INSTRUMENTATION CALIBRATED AFTER EACH MISSION.
3. PROPULSION AND AVIONICS CHECKOUTS TO BE RUN CONCURRENTLY.

TIME IN HOURS

OPTION NUMBER	FUNCTION TITLE	PREPARE/UPDATE M&R SCHEDULE	FLOW BLOCK NO.	1.1.10

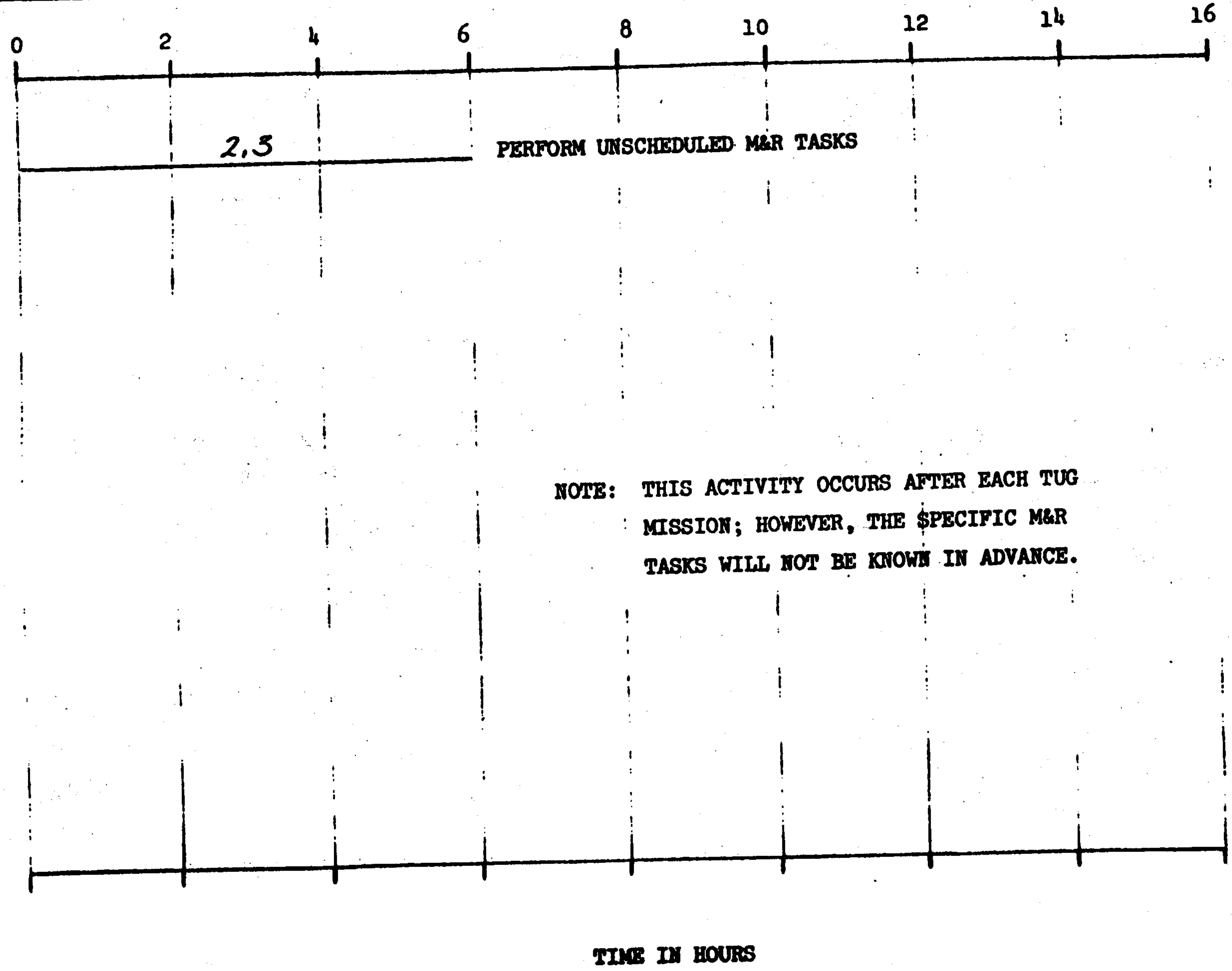


OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
	PERFORM STRUCTURAL/MECHANICAL M&R	1.1.11



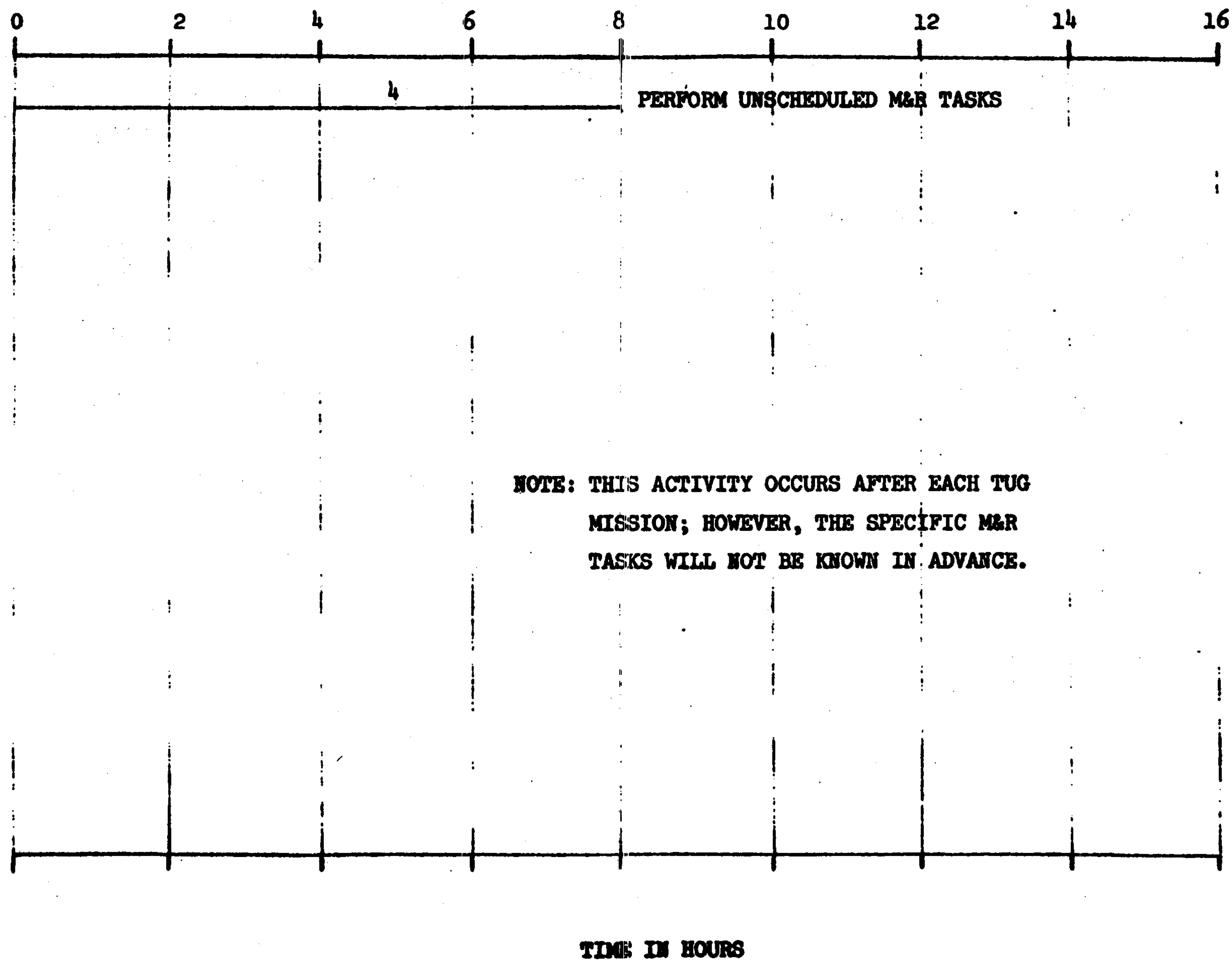
NOTE: THIS ACTIVITY OCCURS AFTER EACH TUG MISSION; HOWEVER, THE SPECIFIC M&R TASKS WILL NOT BE KNOWN IN ADVANCE.

OPTION NUMBER	FUNCTION TITLE	PERFORM PROPULSION M&R	FLOW BLOCK NO.	1.1.12

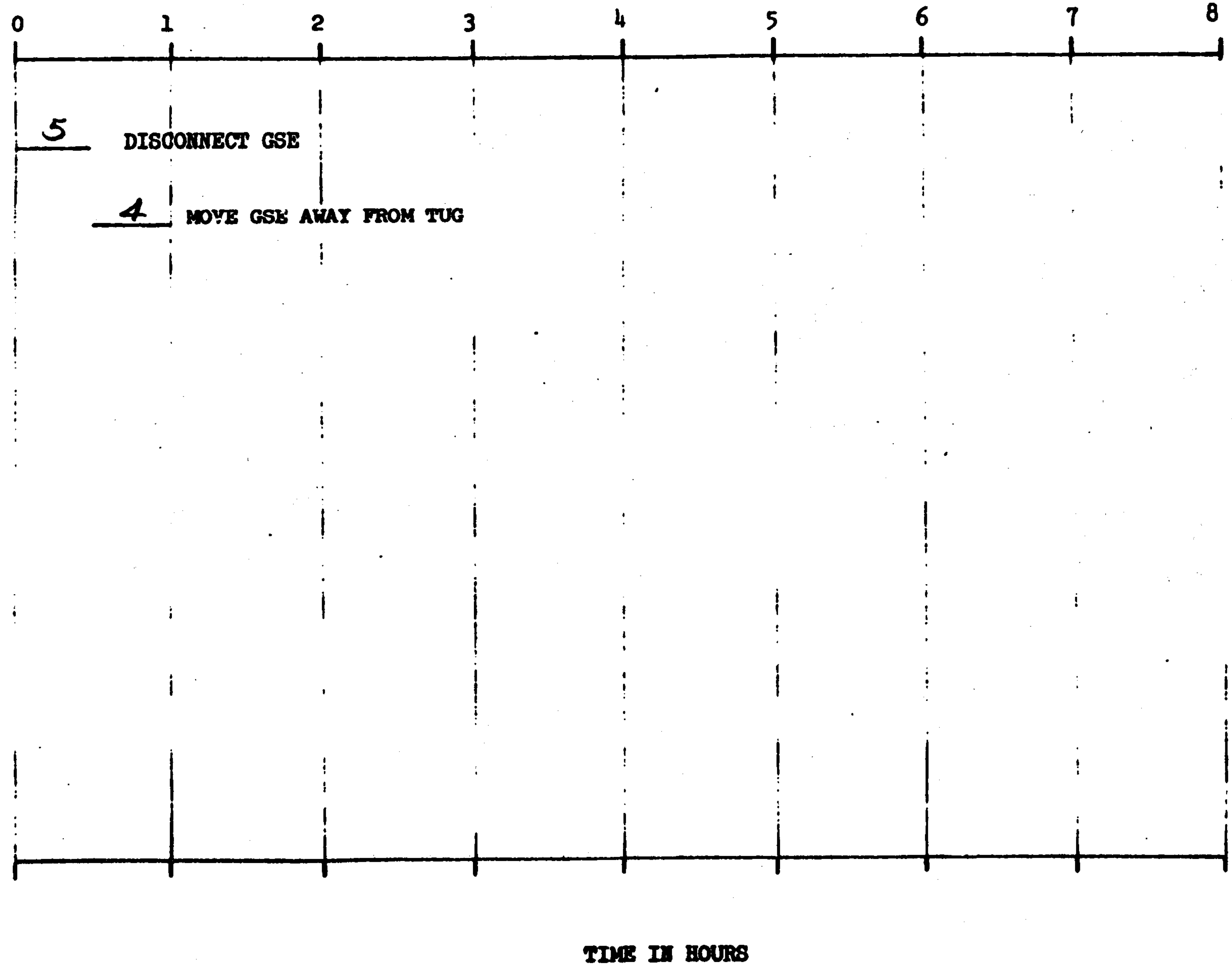


NOTE: THIS ACTIVITY OCCURS AFTER EACH TUG MISSION; HOWEVER, THE SPECIFIC M&R TASKS WILL NOT BE KNOWN IN ADVANCE.

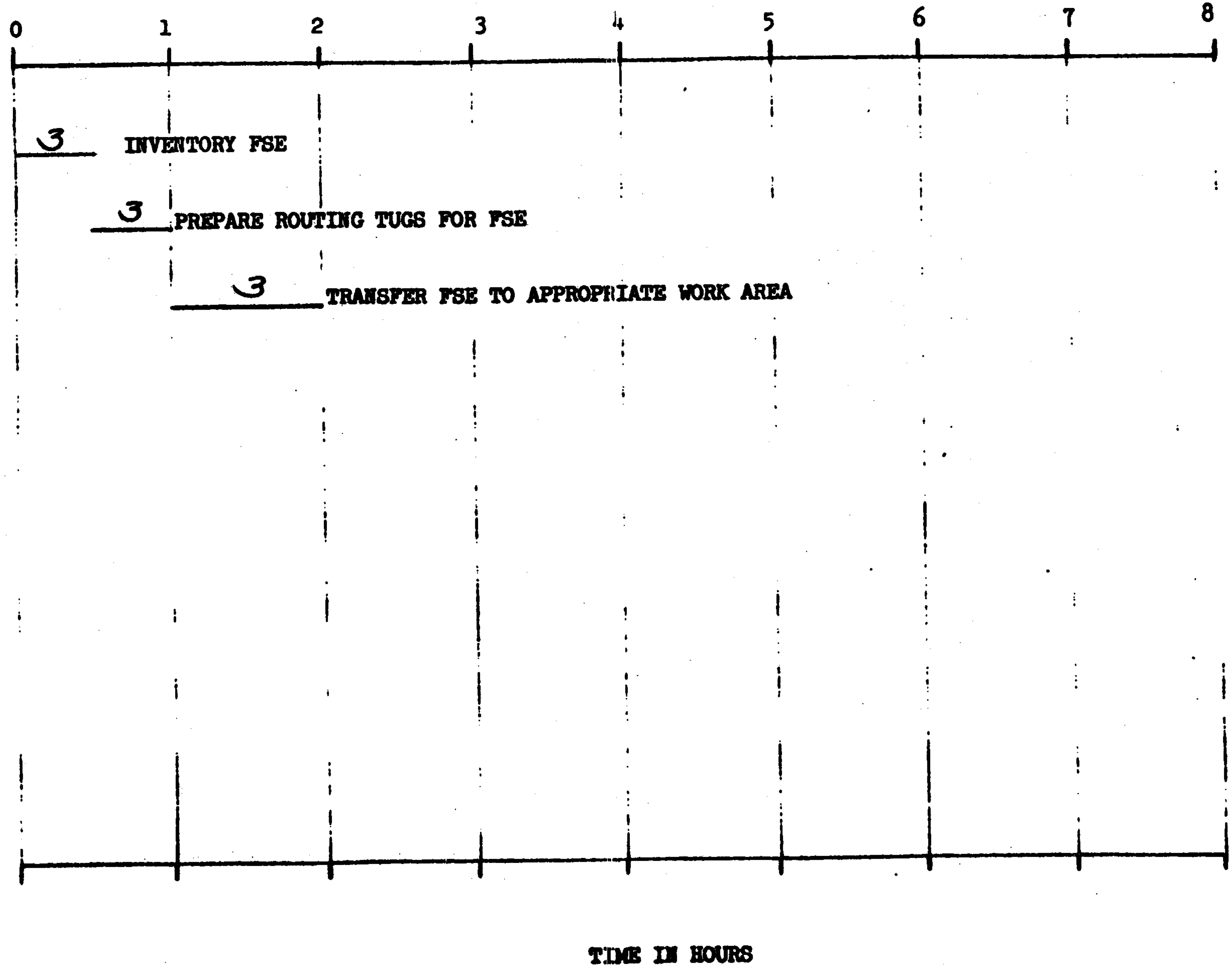
OPTION NUMBER		FUNCTION TITLE	PERFORM AVIONICS M&R	FLOW BLOCK NO.	1.1.13



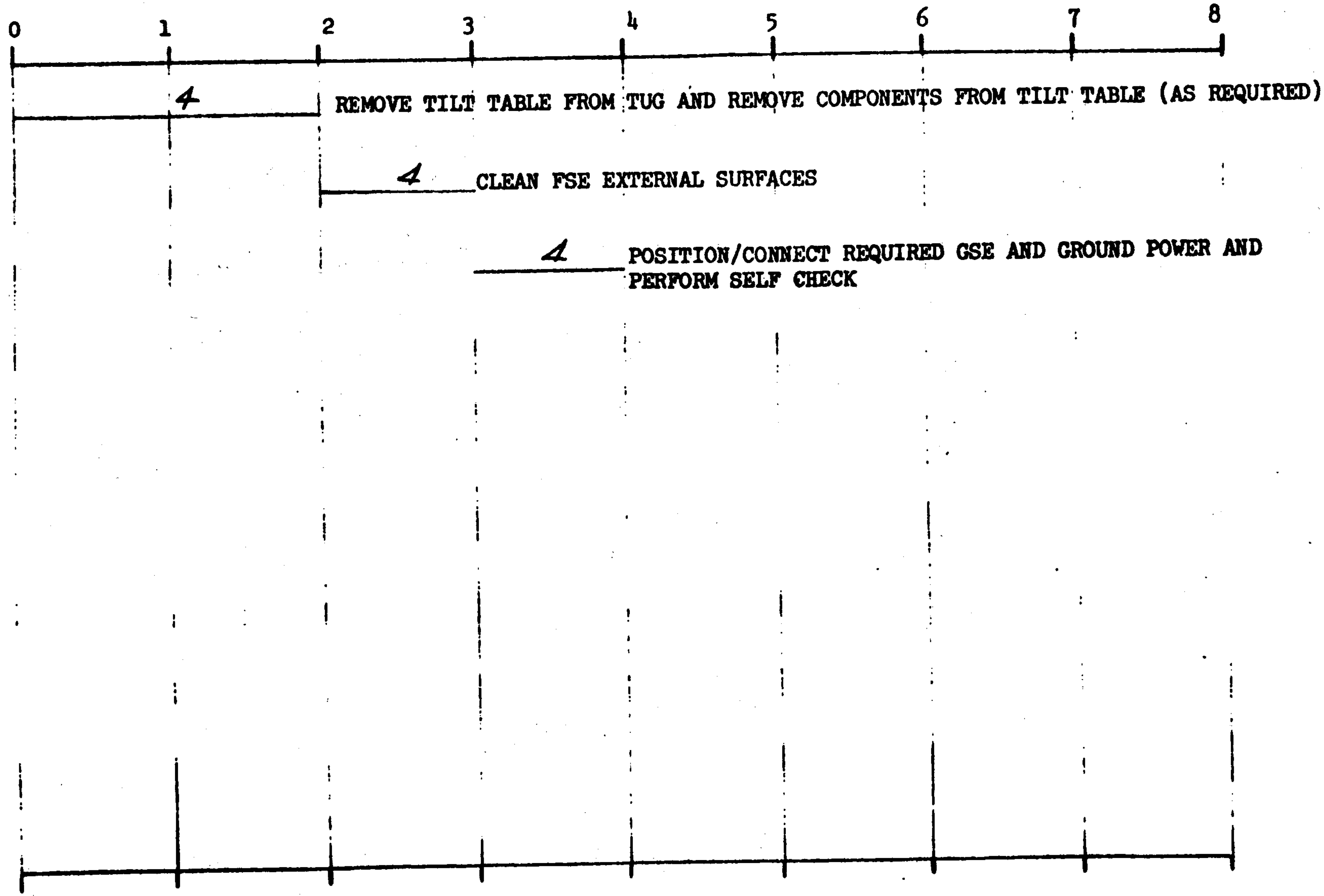
OPTION NUMBER	FUNCTION TITLE REMOVE M&R GSE	FLOW BLOCK NO. 1.1.14



OPTION NUMBER		FUNCTION TITLE	RECEIVE FSE AT TPF/PPF	FLOW BLOCK NO.	1.1.15

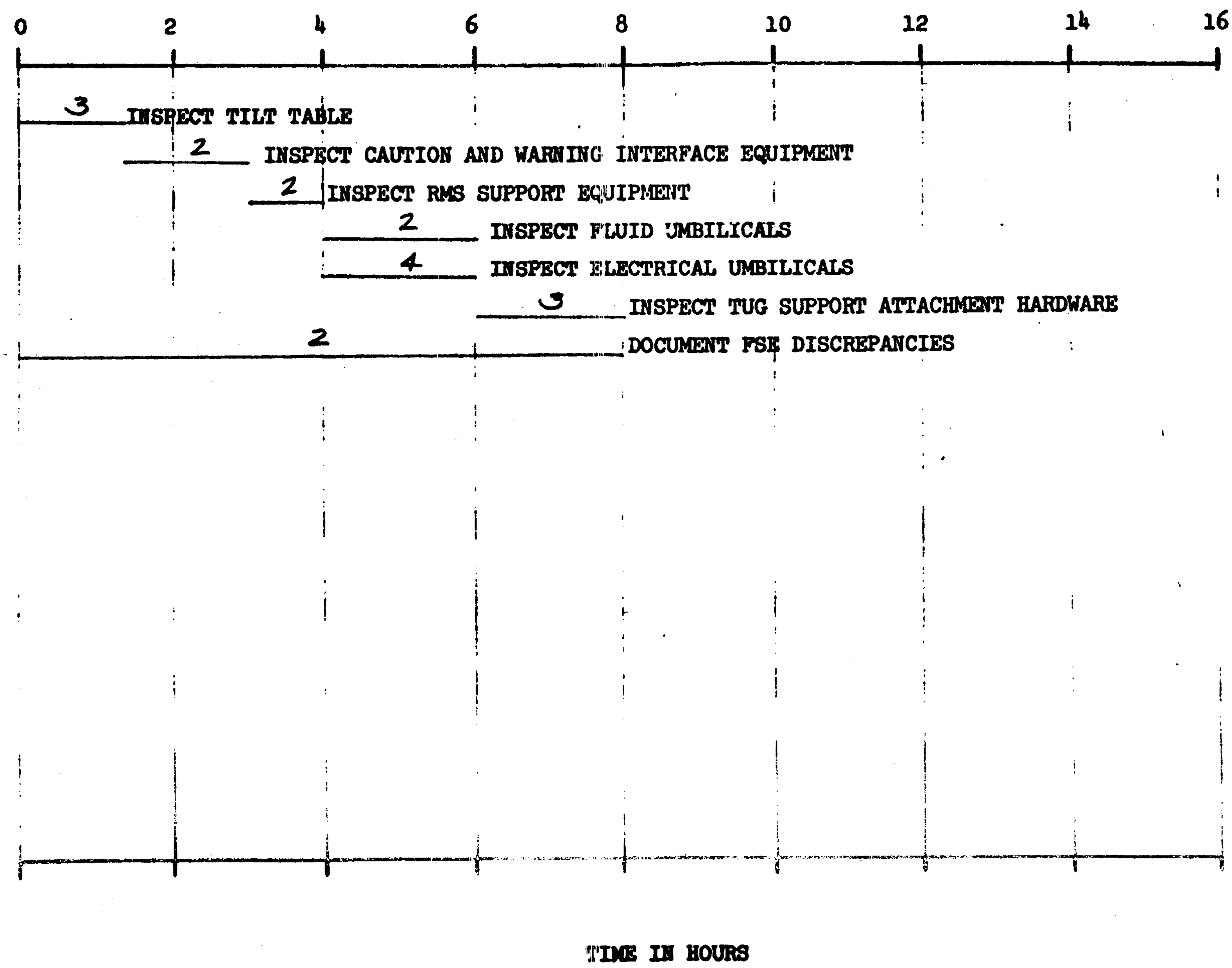


OPTION NUMBER	FUNCTION TITLE PREPARE FOR INSPECTION	FLOW BLOCK NO. 1.1.16

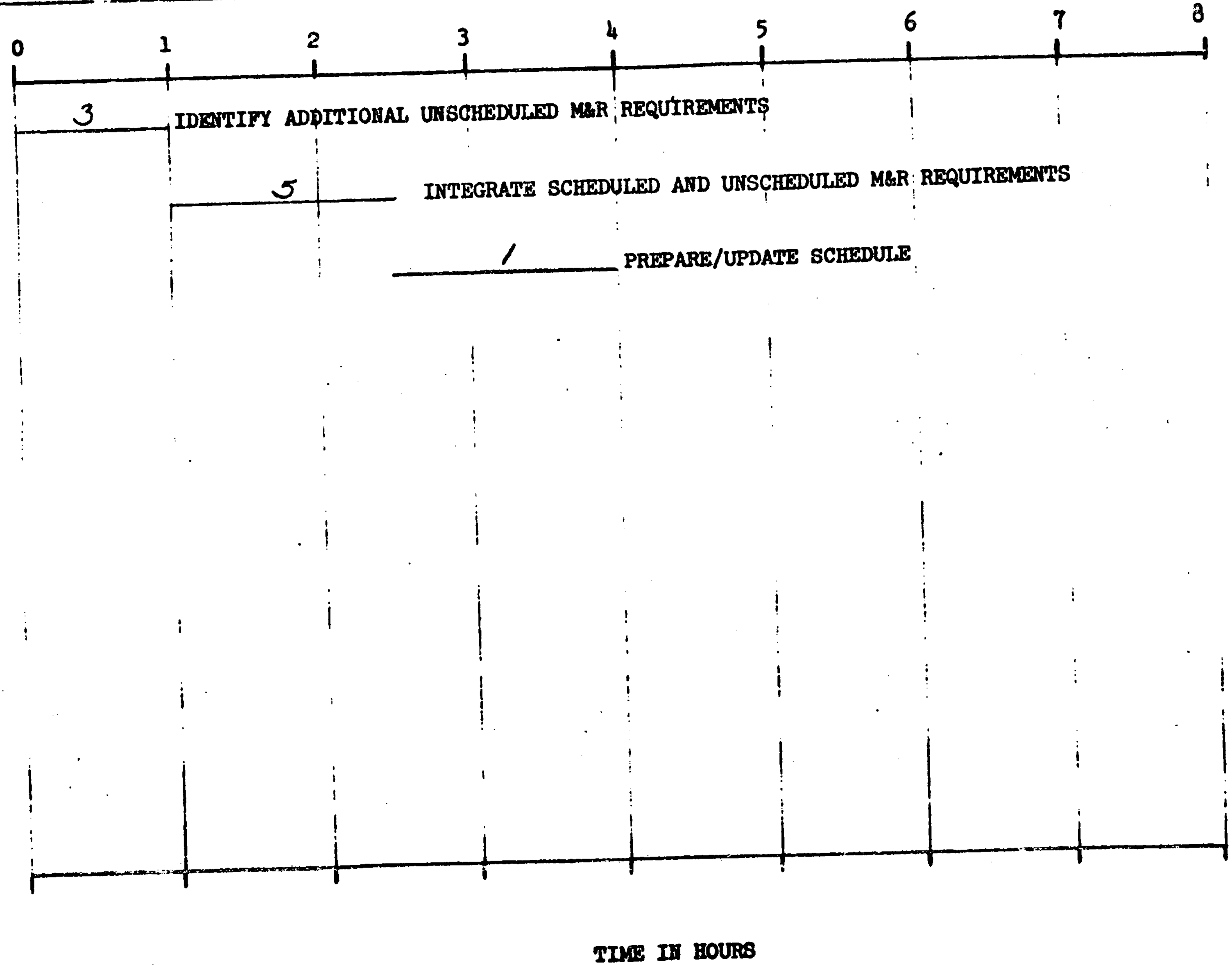


TIME IN HOURS

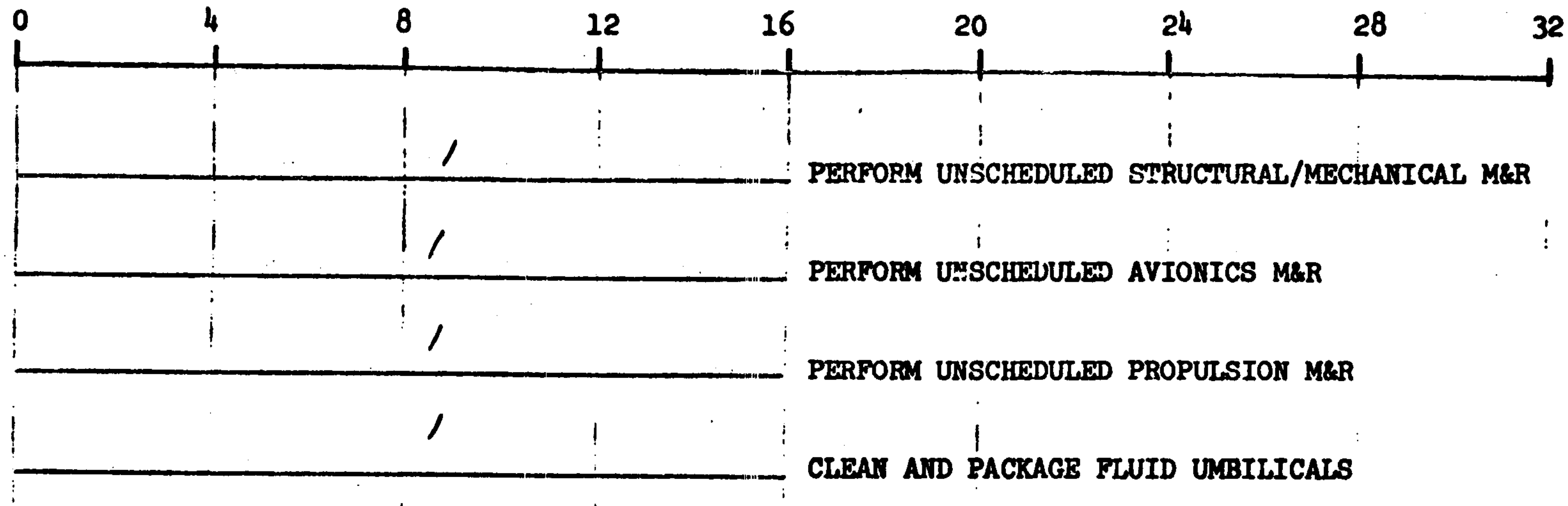
OPTION NUMBER		FUNCTION TITLE	PERFORM FSE POST FLIGHT/RECEIVING INSPECTION	FLOW BLOCK NO.	1.1.17



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
	PREPARE/UPDATE M&R SCHEDULE	1.1.18



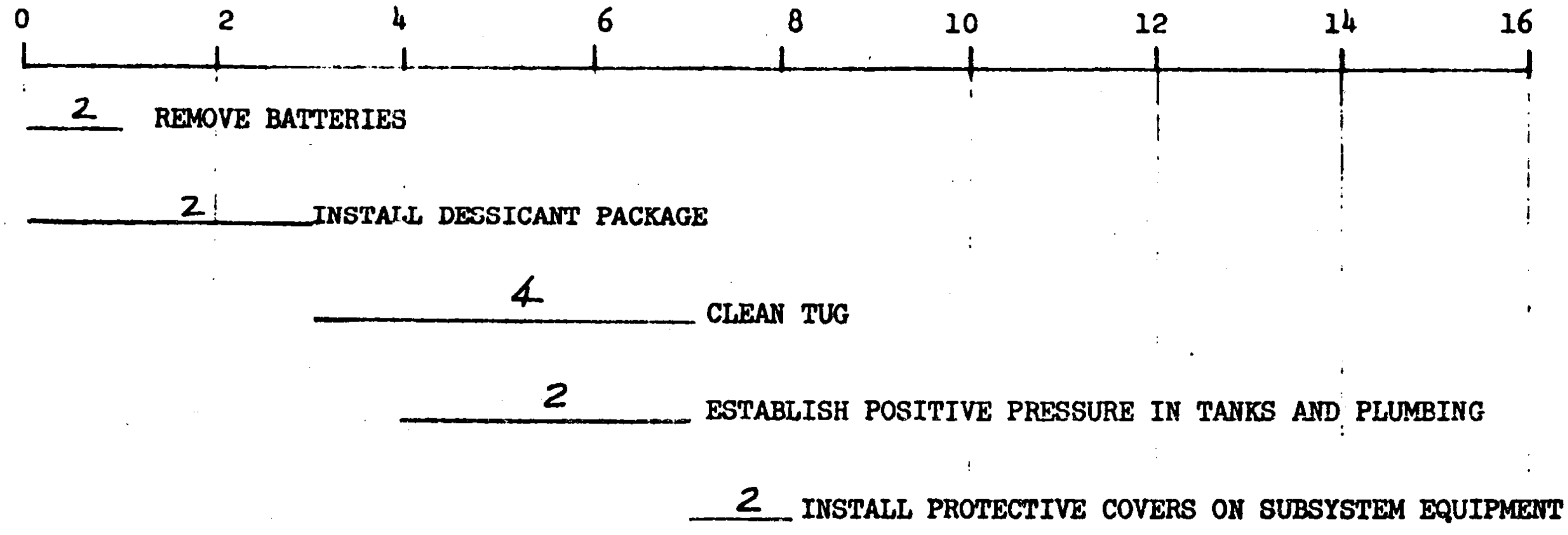
OPTION NUMBER	FUNCTION TITLE PERFORM FSE M&R	FLOW BLOCK NO. 1.1.19



NOTE: THIS ACTIVITY OCCURS AFTER EACH TUG MISSION; HOWEVER, THE MAGNITUDE OF INDIVIDUAL SUBSYSTEM UNSCHEDULED M&R TOGETHER WITH RELATED SKILL REQUIREMENTS WILL VARY.

TIME IN HOURS

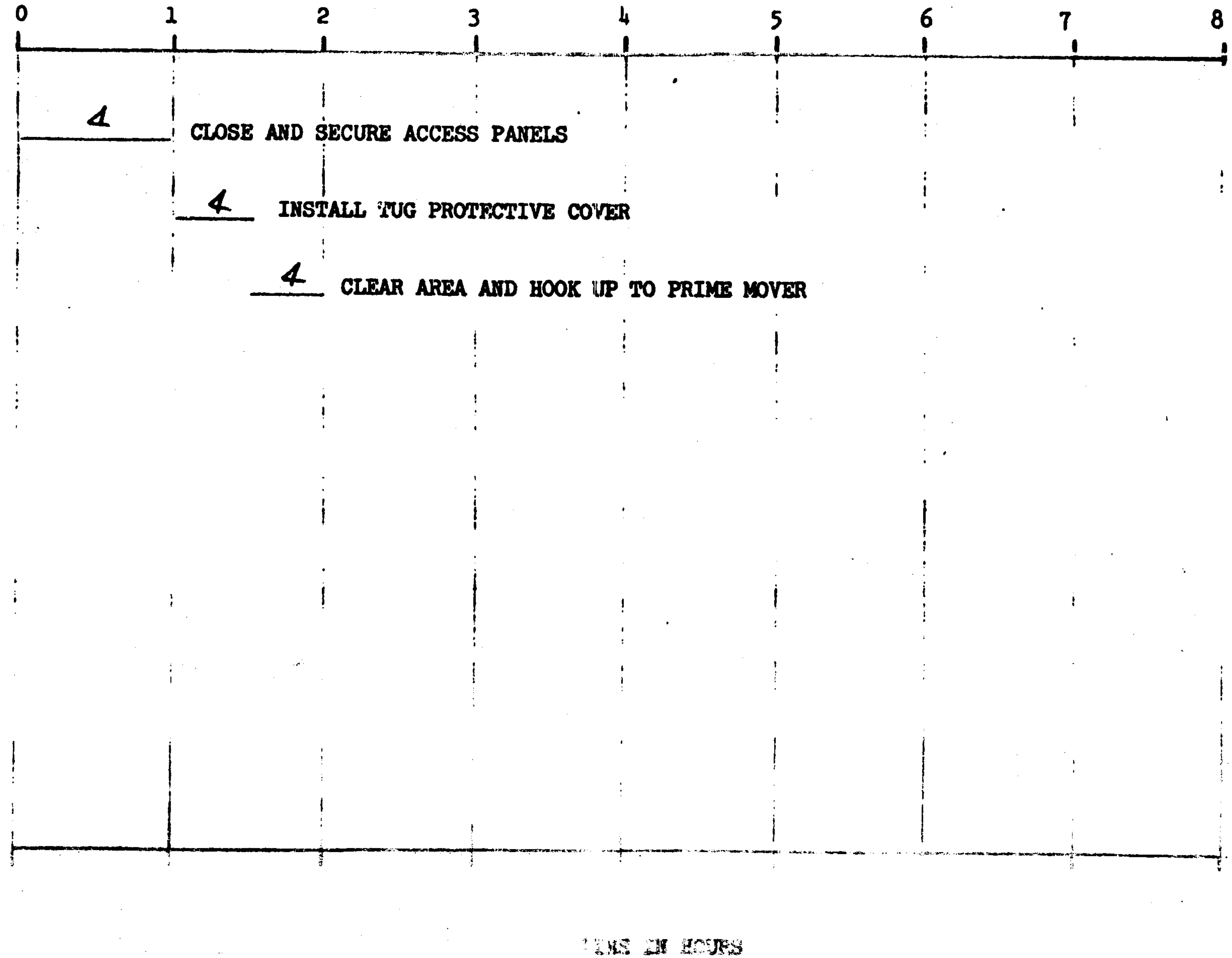
OPTION NUMBER	FUNCTION TITLE PREPARE FOR STORAGE	FLOW BLOCK NO. 1.1.20



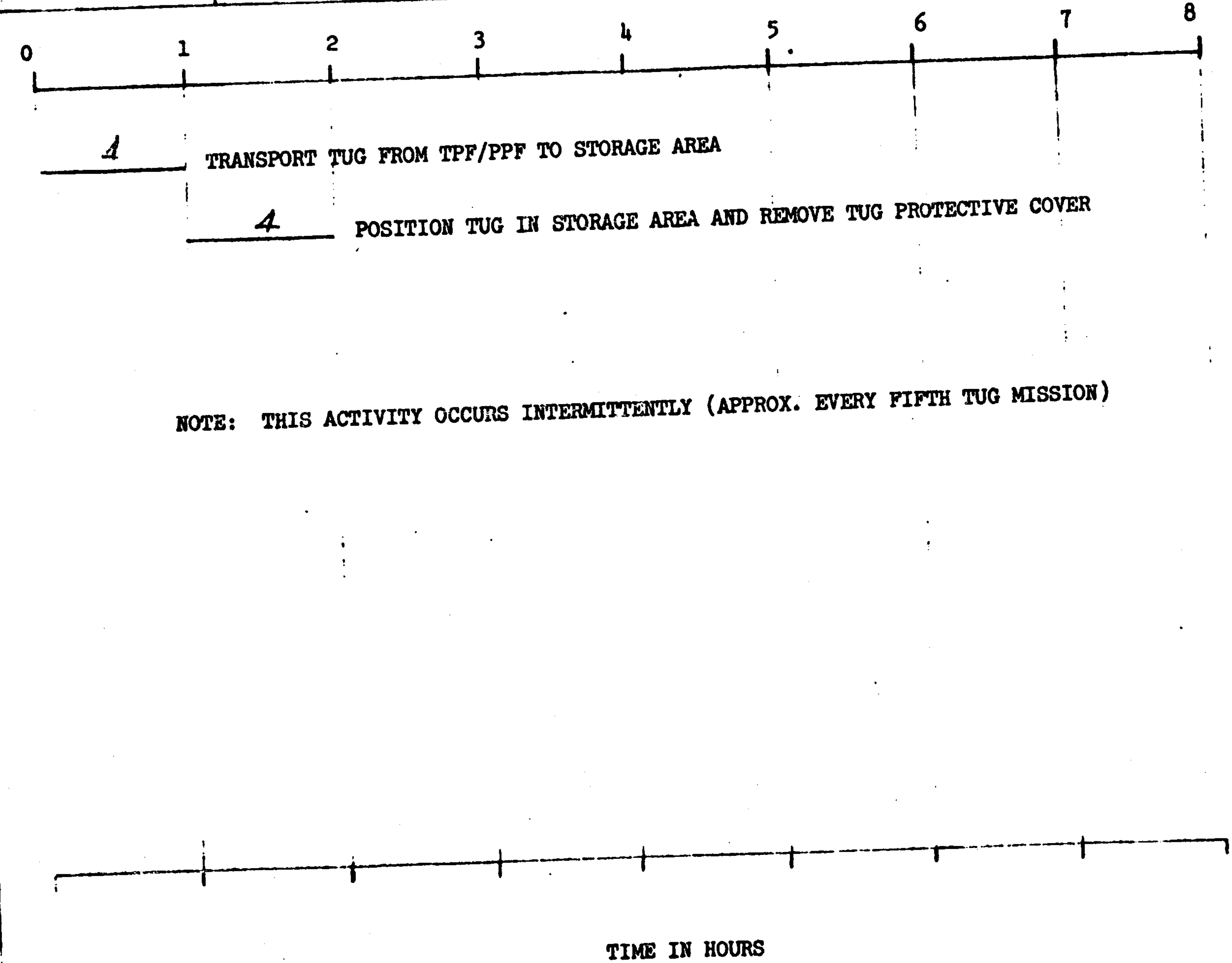
NOTE: THIS ACTIVITY OCCURS INTERMITTENTLY (APPROX. EVERY FIFTH TUG MISSION)

TIME IN HOURS

OPTION NUMBER	FUNCTION TITLE	PREPARE FOR TRANSPORT	FLOW BLOCK NO.	1.1.2 1



OPTION NUMBER	FUNCTION TITLE TRANSFER TO STORAGE	FLOW BLOCK NO. 1.1.22



OPTION NUMBER	FUNCTION TITLE PERFORM STORAGE SUPPORT	FLOW BLOCK NO. 1.1.23

0 1 2 3 4 5 6 7 8

4 INSPECT DESSICANT PACKAGES AND MONITOR PURGES

4 SERVICE/REPLACE DESSICANT PACKAGES AND PURGE LEVELS

4 MAINTAIN RECORDS AND LOGS

4 PERFORM OTHER PNEUMATIC MAINTENANCE AS REQUIRED

NOTE: THIS ACTIVITY IS PERFORMED PERIODICALLY WHILE TUG IS IN STORAGE

TIME IN HOURS

OPTION NUMBER	FUNCTION TITLE REMOVE FROM STORAGE	FLOW BLOCK NO. 1.1.24

0 1 2 3 4 5 6 7 8

4 INSPECT TUG FOR GENERAL CONDITION

4 CHECK RECORDS/LOGS AND IDENTIFY SUBSYSTEM DISCREPANCIES

4 INSTALL TUG PROTECTIVE COVER

4 PREPARE FOR TRANSPORT

NOTE: THIS ACTIVITY OCCURS EACH TIME A TUG IS REMOVED FROM STORAGE

TIME IN HOURS

OPTION NUMBER	FUNCTION TITLE TRANSFER TO TPF/PPF (FOR M&R)	FLOW BLOCK NO. 1.1.25

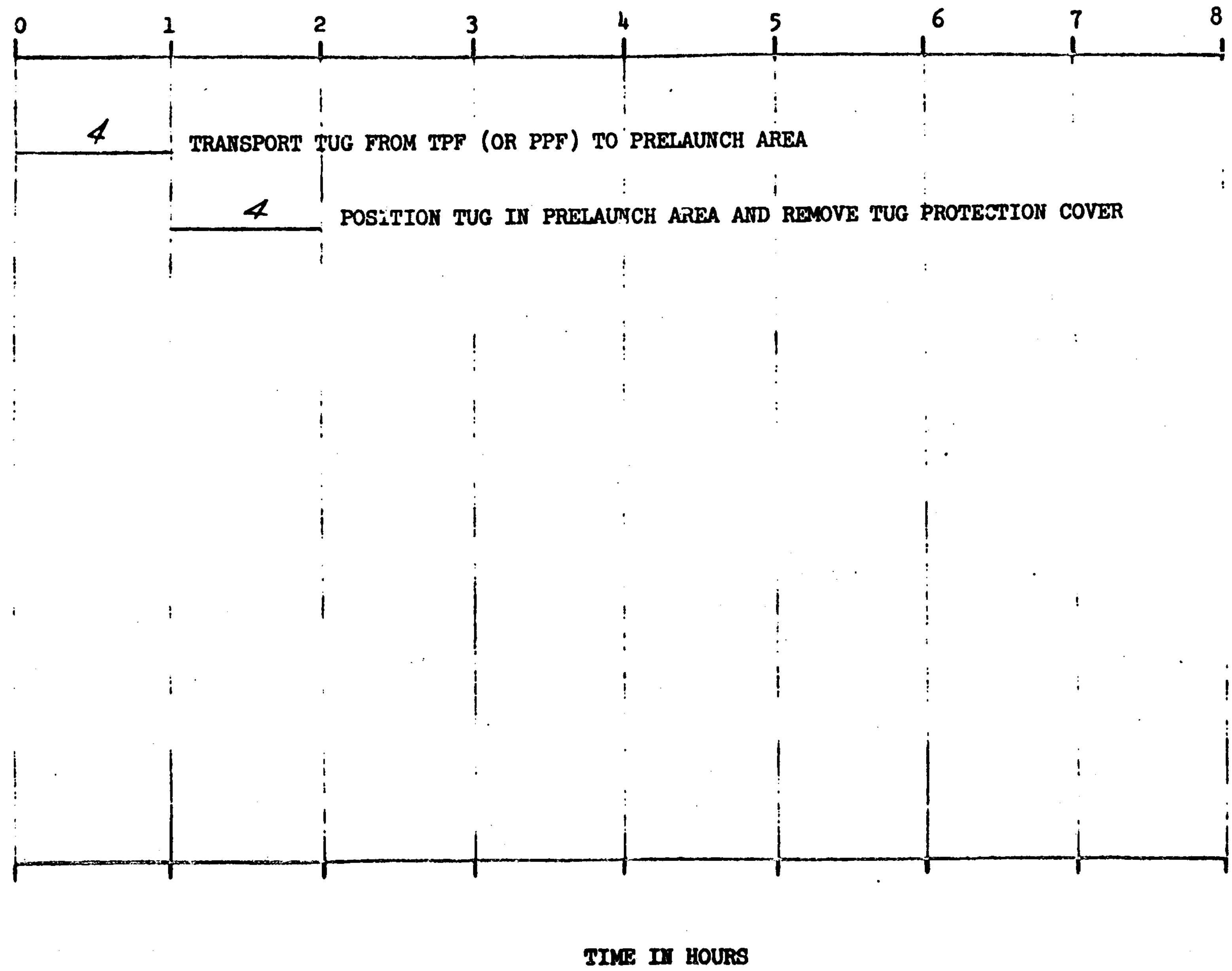
0 1 2 3 4 5 6 7 8

4 TRANSPORT TUG FROM STORAGE AREA TO TPF/PPF

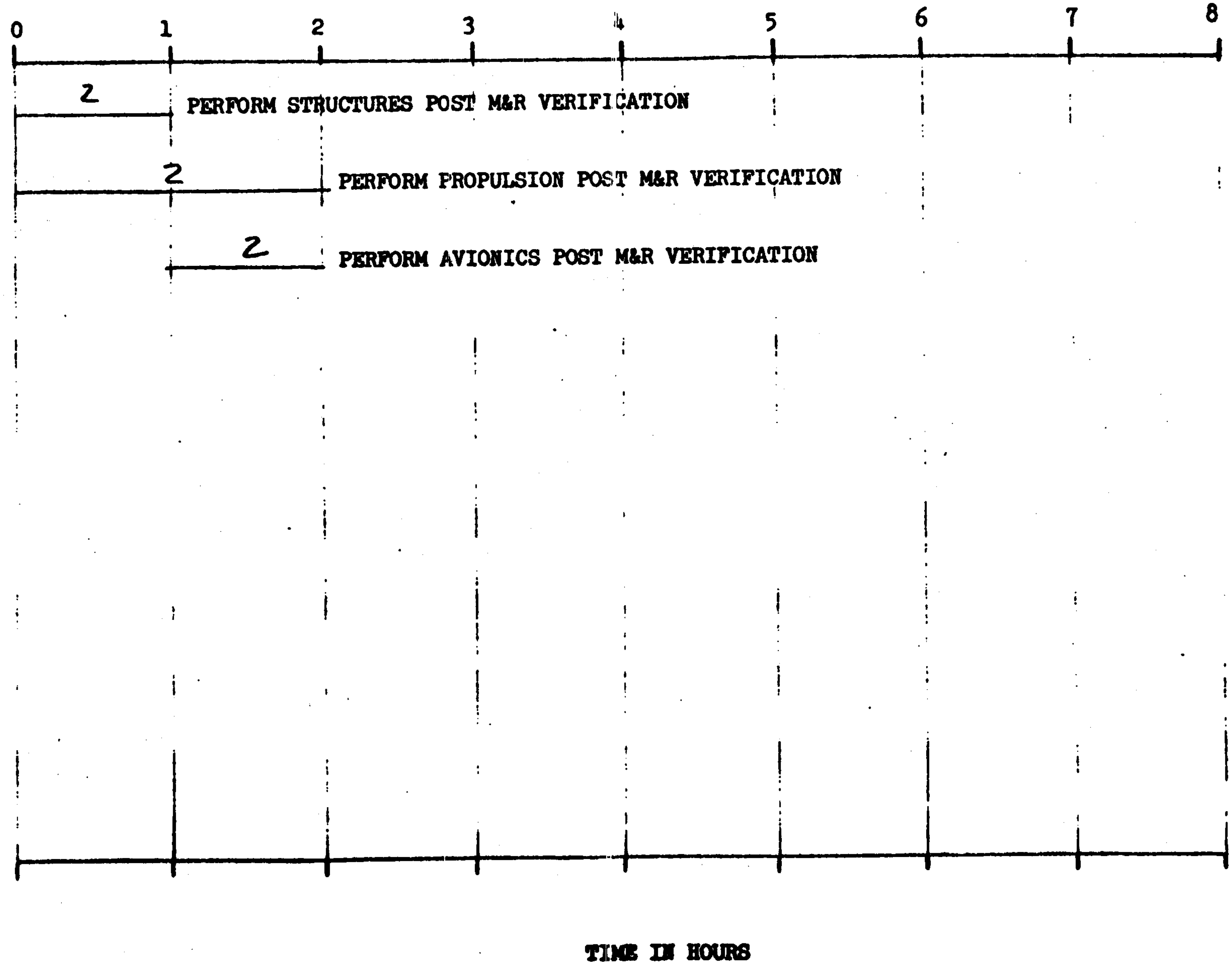
NOTE: THIS ACTIVITY OCCURS EACH TIME A TUG IS REMOVED FROM STORAGE

TIME IN HOURS

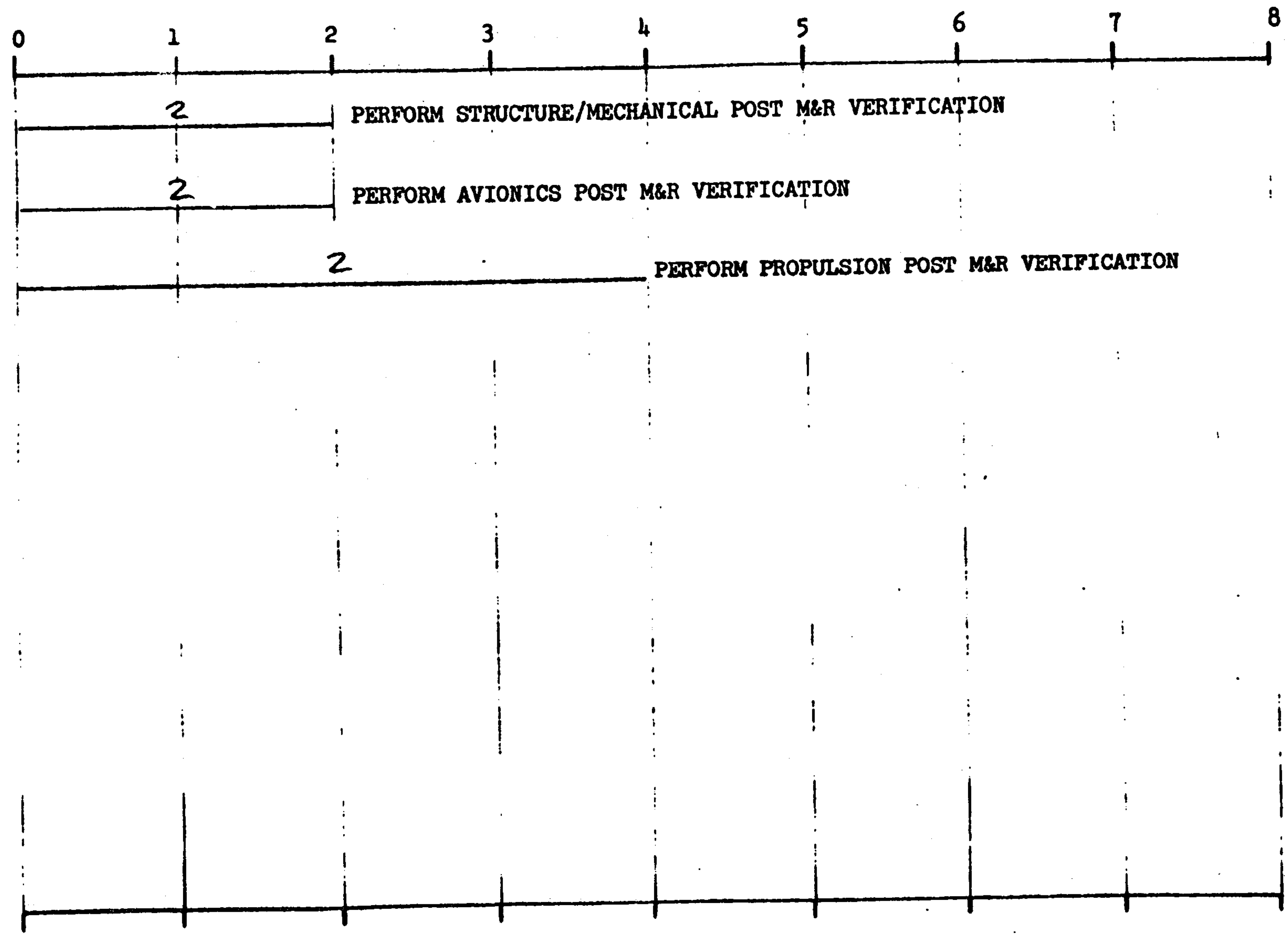
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
	TRANSFER TO PRELAUNCH	1.1.2 6



OPTION NUMBER	FUNCTION TITLE POST M&R VERIFICATION	FLOW BLOCK NO. 1.2.1

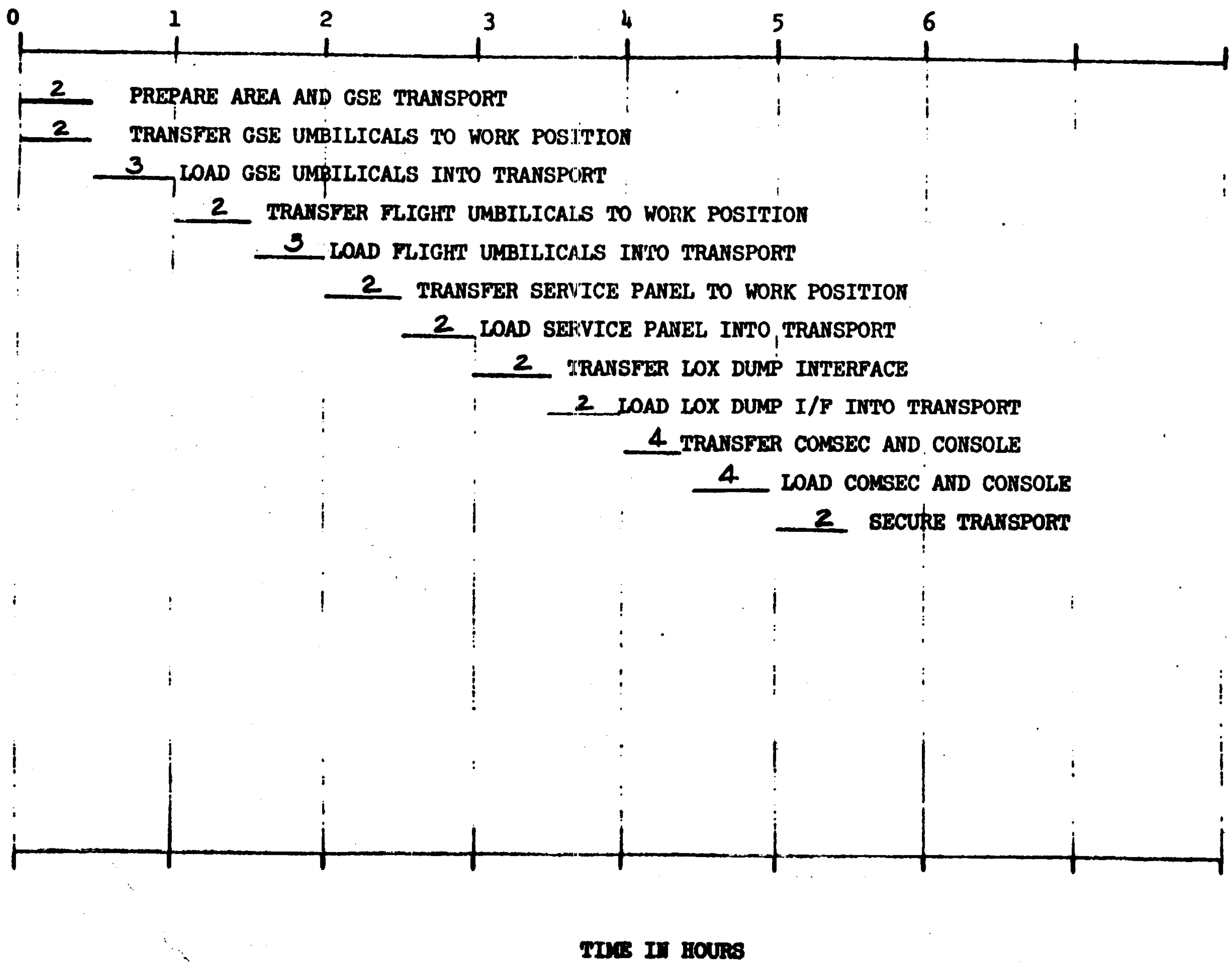


OPTION NUMBER	FUNCTION TITLE	PERFORM POST M&R VERIFICATION - FSE	FLOW BLOCK NO.	1.2.2

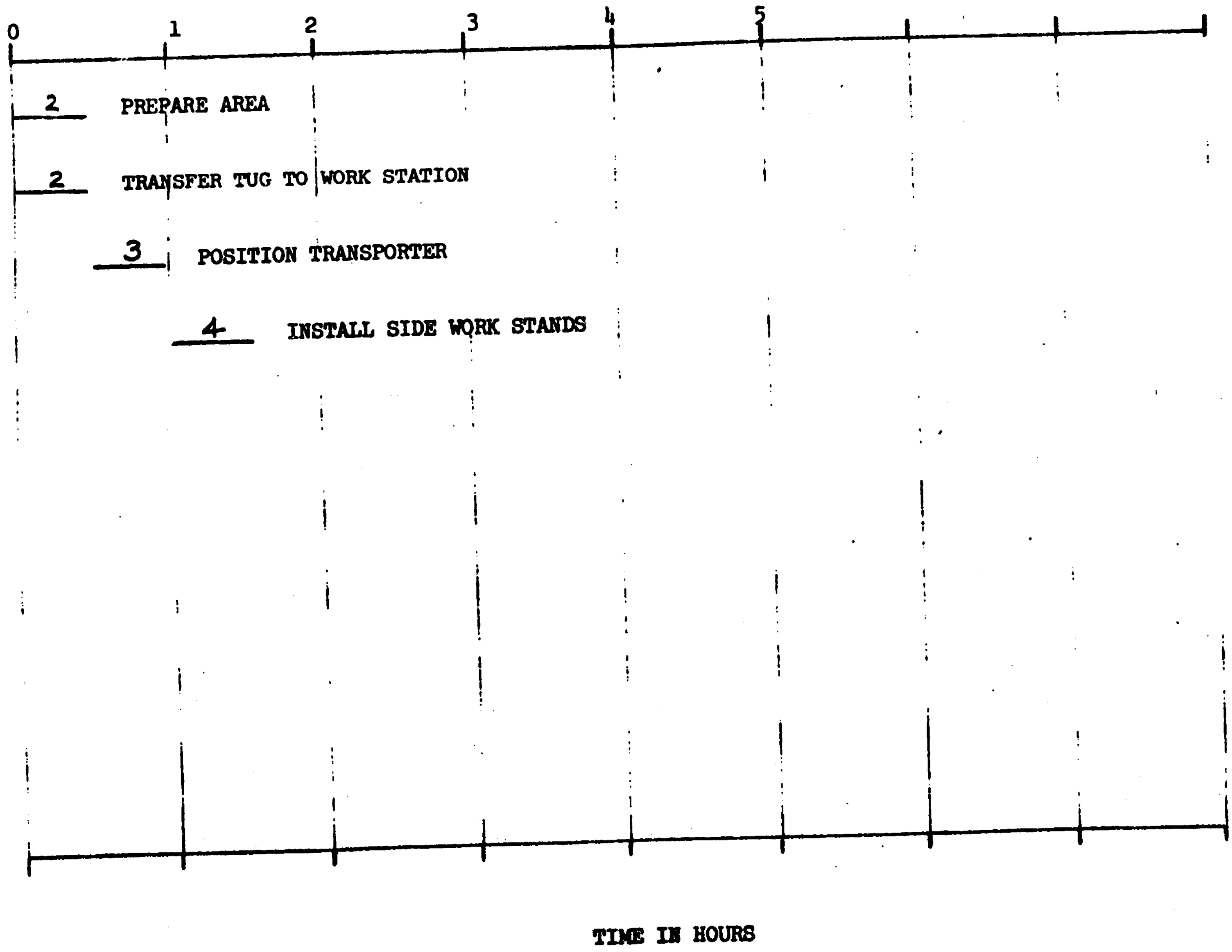


TIME IN HOURS

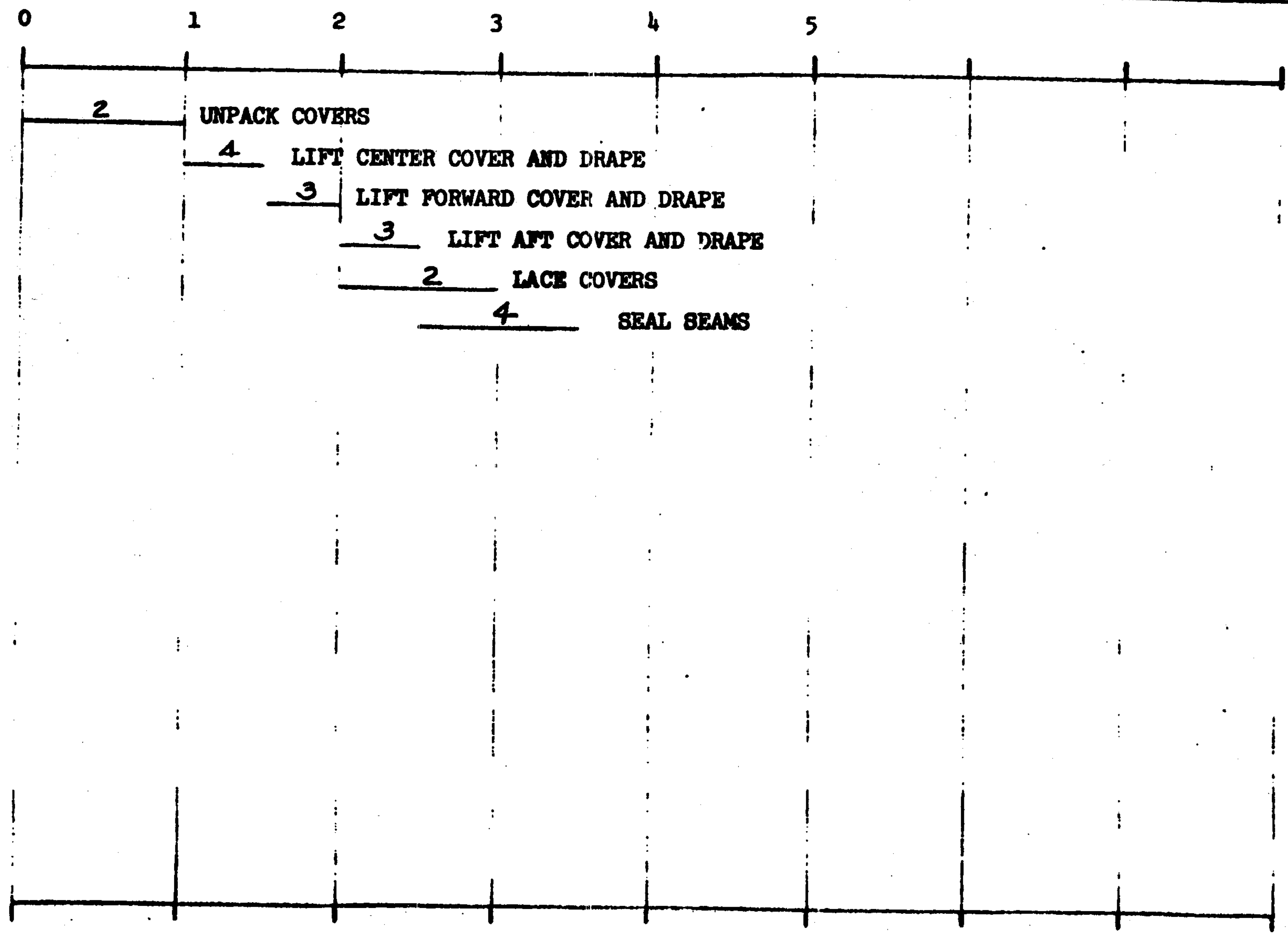
OPTION NUMBER	FUNCTION TITLE	RECEIVE FSE FROM M&R	FLOW BLOCK NO.	2.1.1



OPTION NUMBER	FUNCTION TITLE RECEIVE TUG FROM M&R	FLOW BLOCK NO. 2.1.2

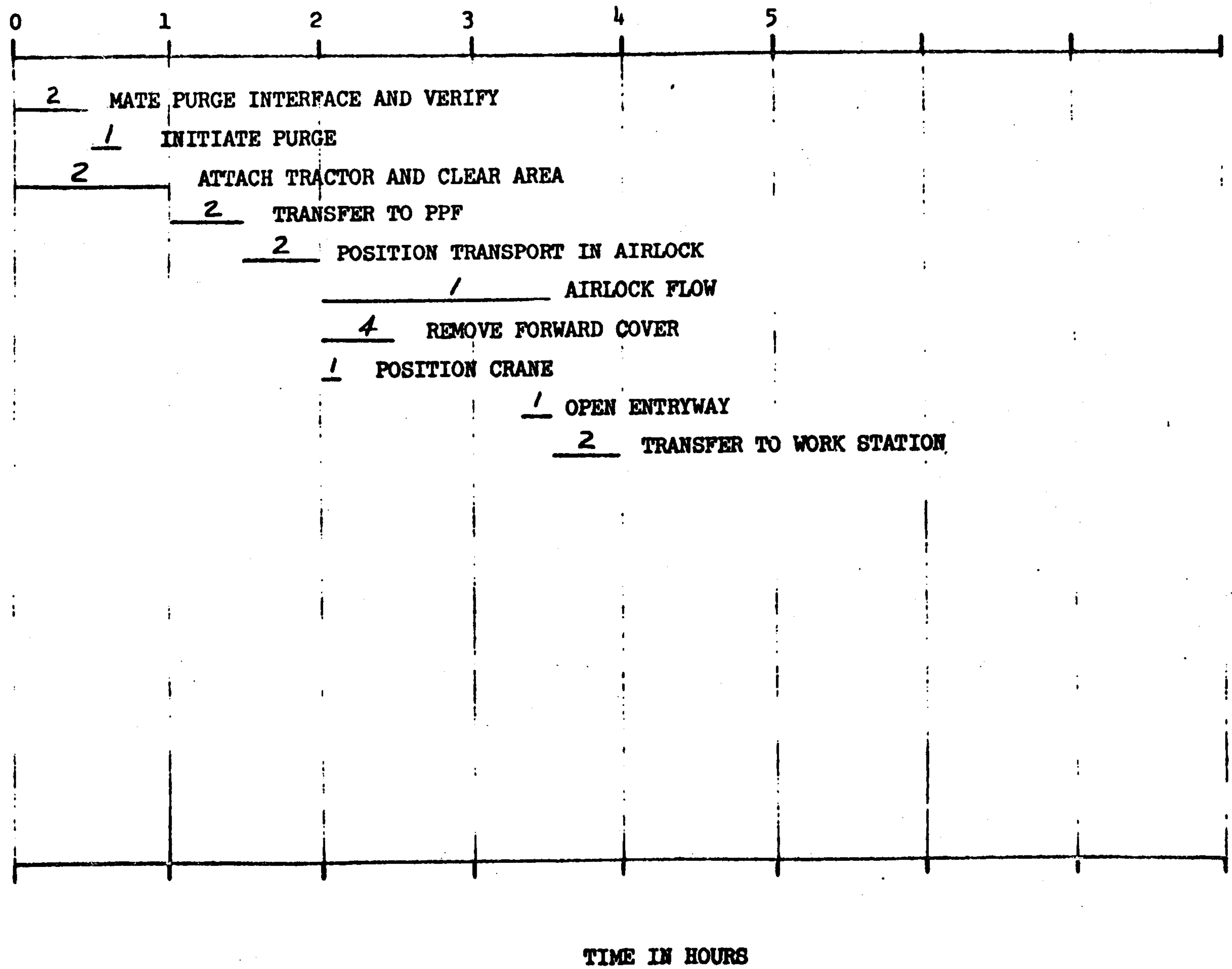


OPTION NUMBER	FUNCTION TITLE PREPARE TUG FOR PPF TRANSFER	FLOW BLOCK NO. 2.1.3

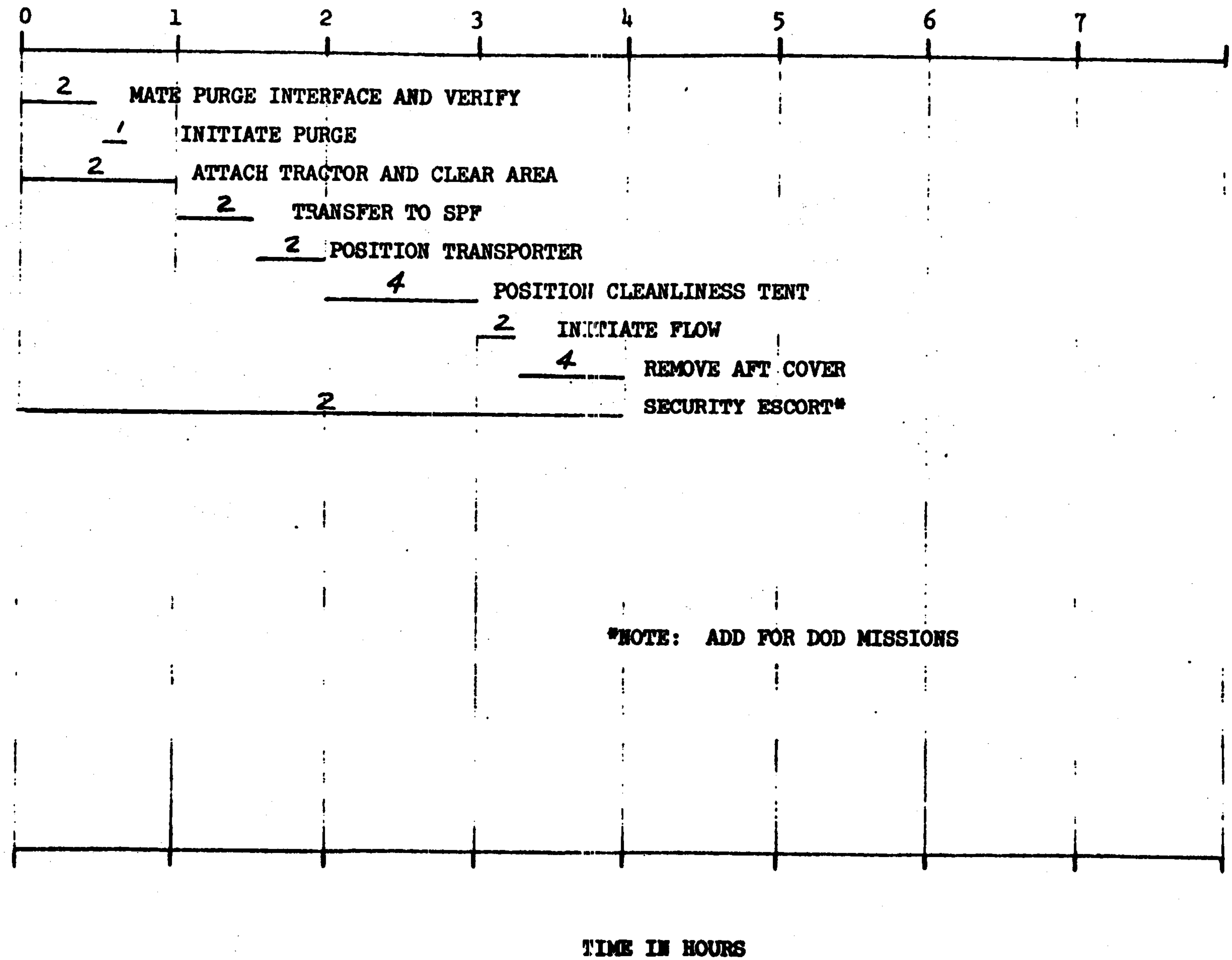


TIME IN HOURS

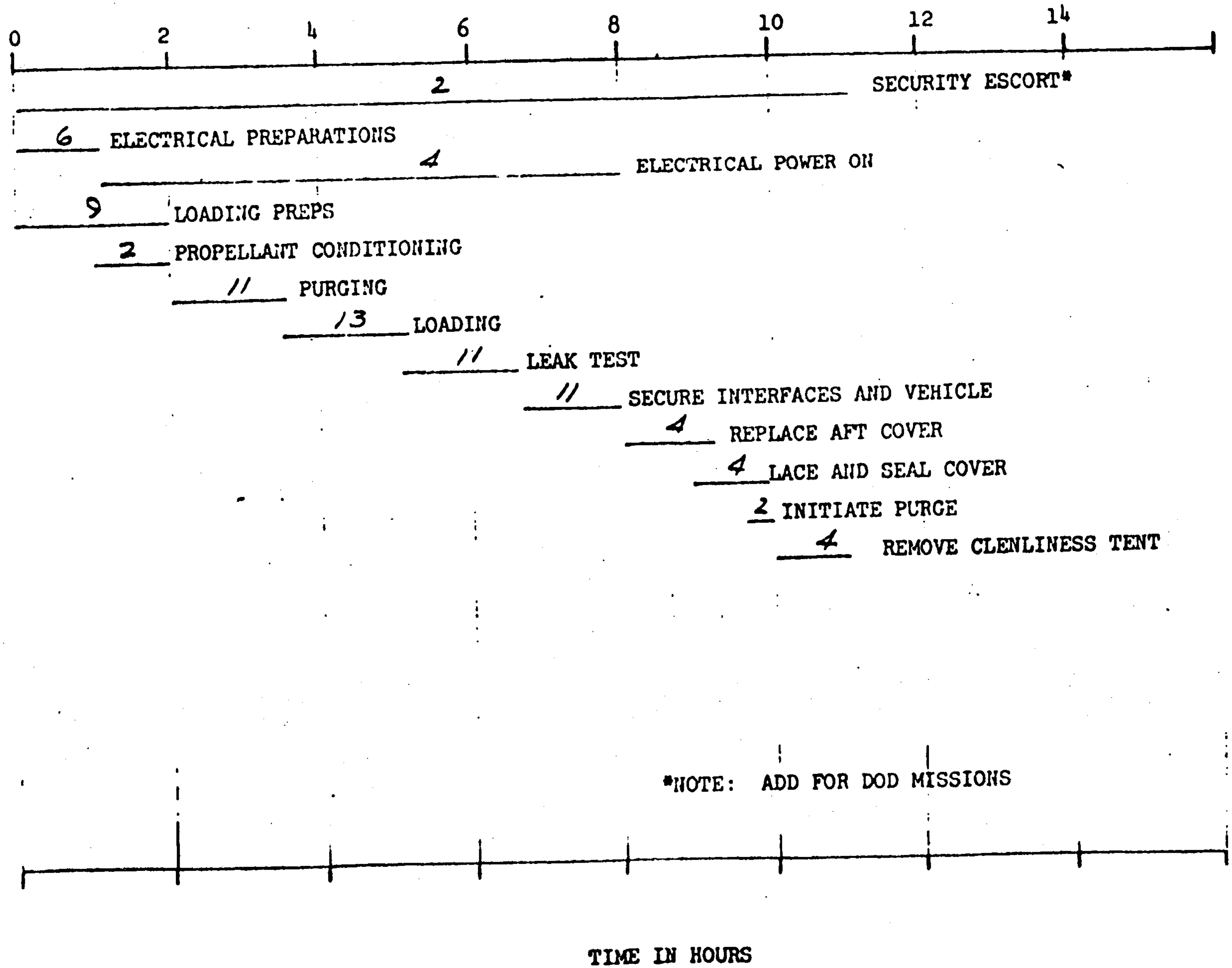
OPTION NUMBER	FUNCTION TITLE	TRANSFER TUG TO PPF	FLOW BLOCK NO.	2.1.4



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
	TRANSFER PAYLOAD TO SPF	2.1.5

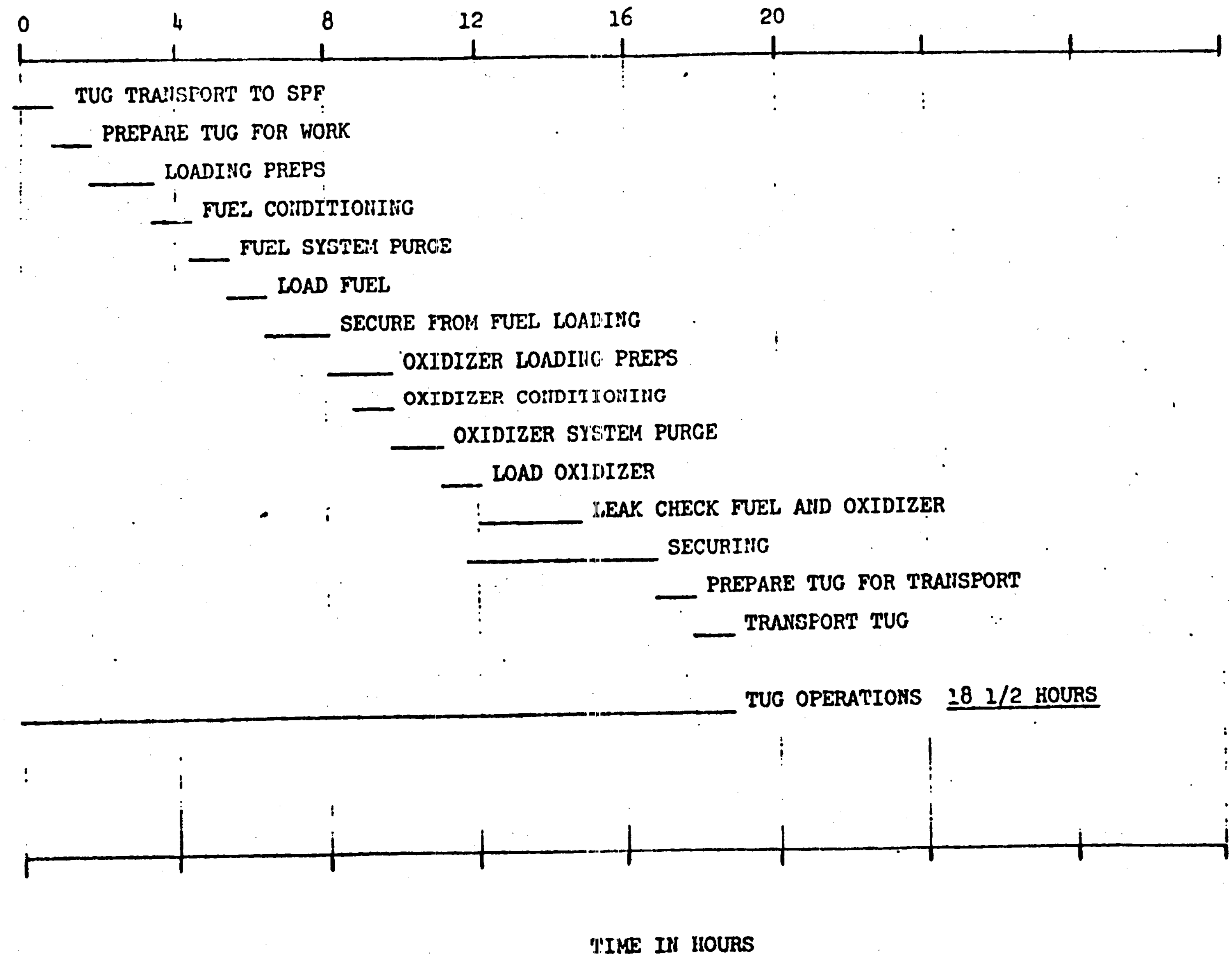


OPTION NUMBER	FUNCTION TITLE STORABLE PROPELLANT SERVICING	FLOW BLOCK NO. 2.1.7

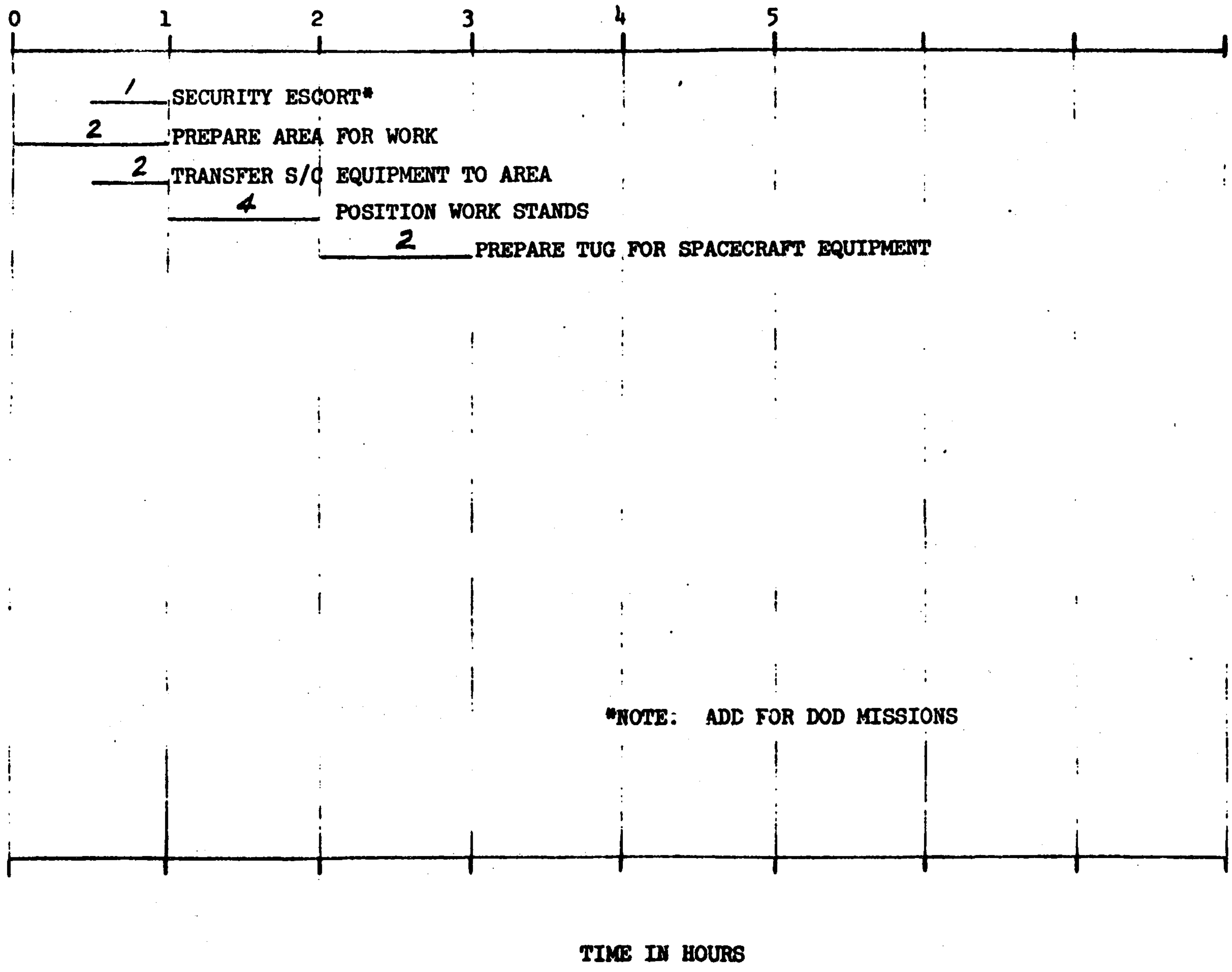


NOTE: MONOPROPELLANT AT SPF

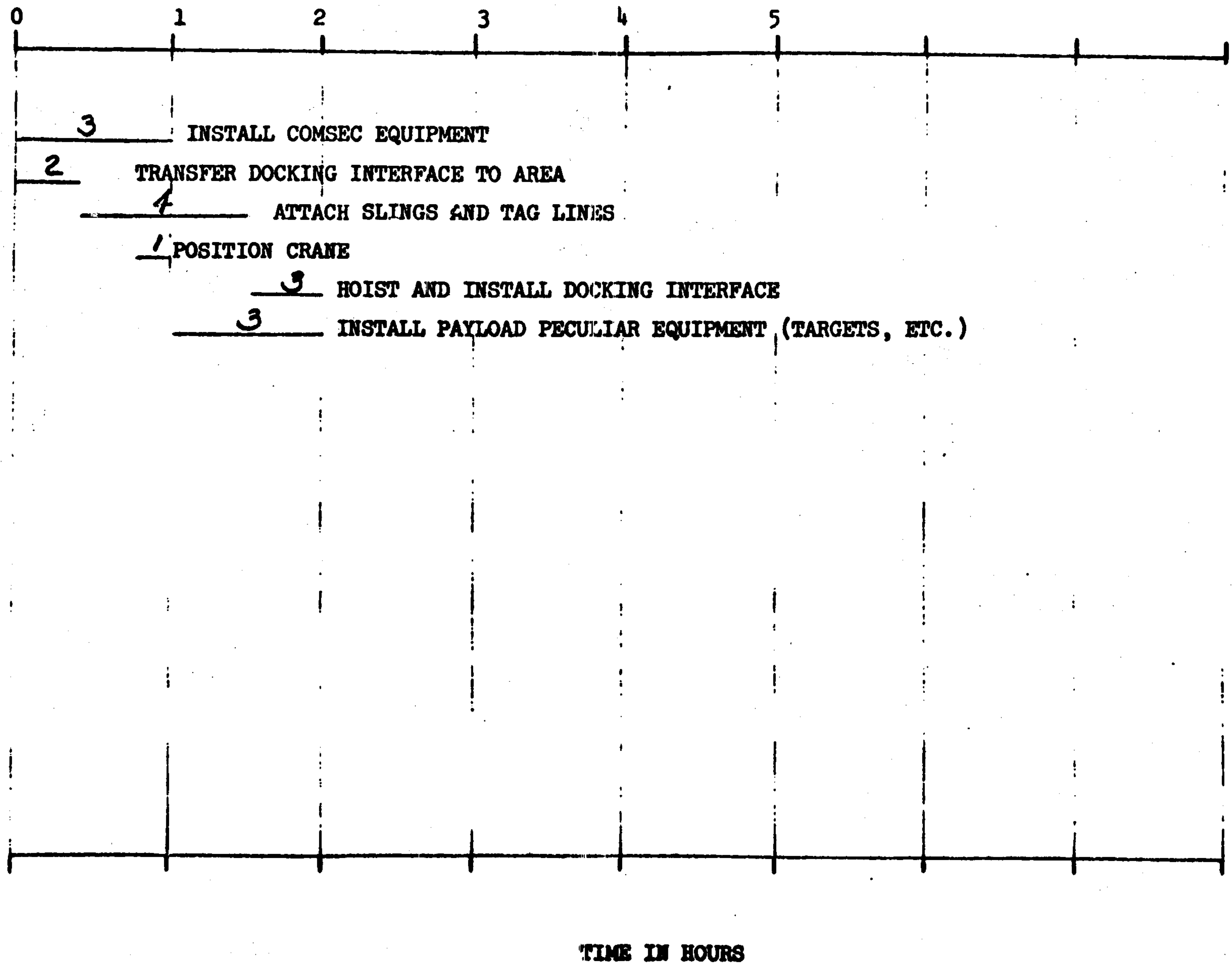
OPTION NUMBER	FUNCTION TITLE BIPROPELLANT APS LOADING AT SPF INTEGRAL SYSTEM	FLOW BLOCK NO. 2.1.8



OPTION NUMBER	FUNCTION TITLE	PREPARE FOR SPACECRAFT EQUIPMENT	FLOW BLOCK NO.	2.2.1.1

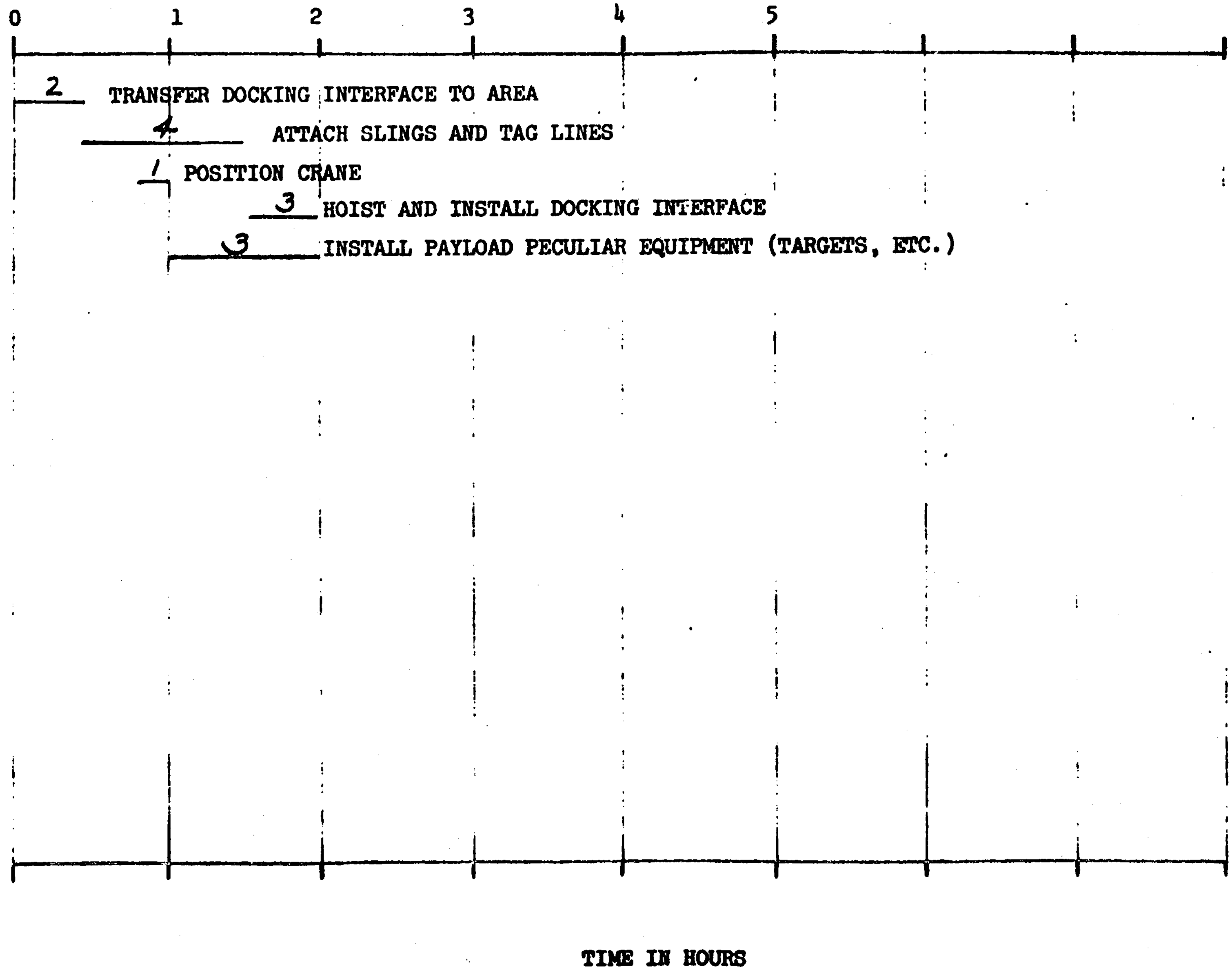


OPTION NUMBER	FUNCTION TITLE: INSTALL SPACECRAFT EQUIPMENT	FLOW BLOCK NO. 2.2.1.2.a



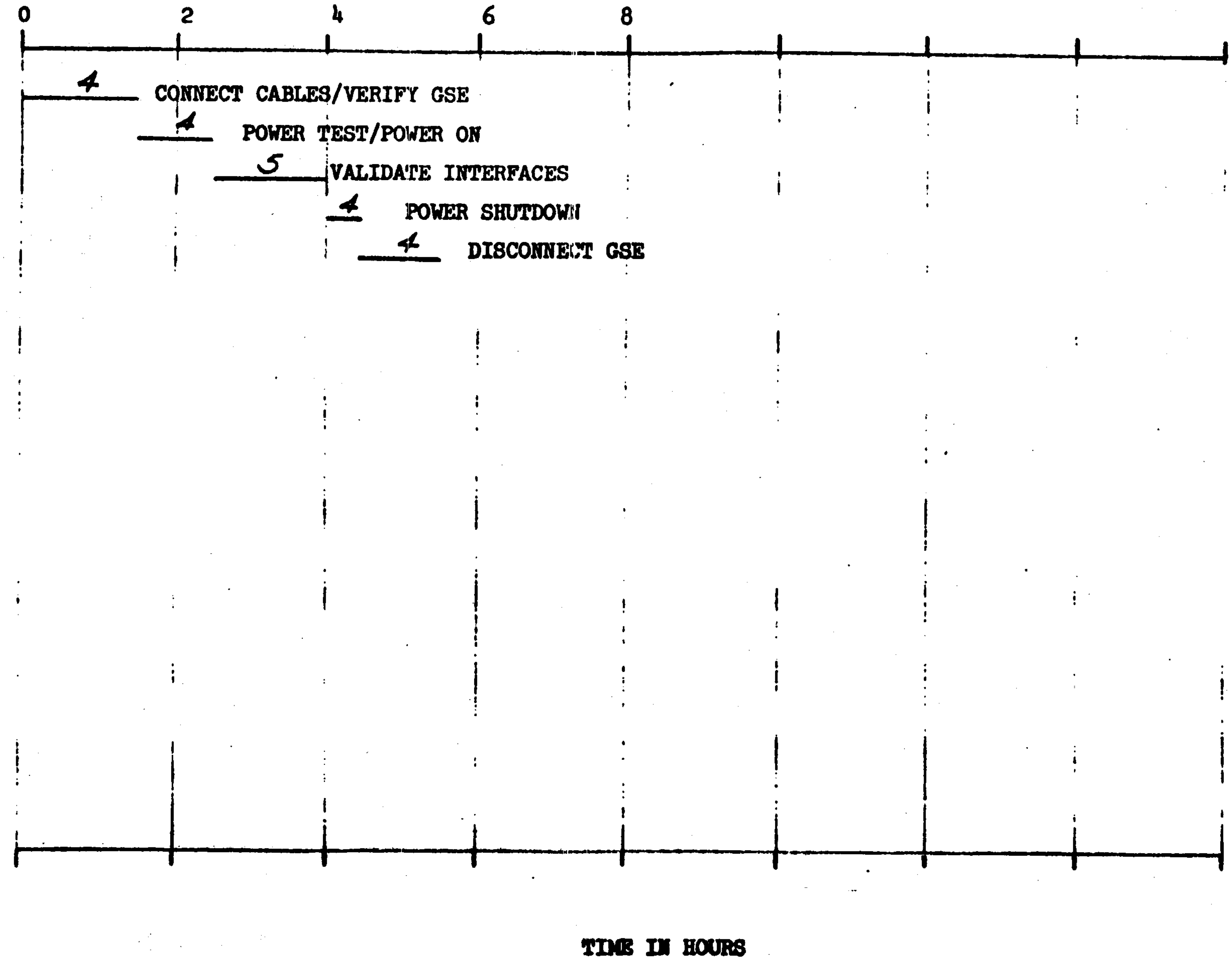
NOTE: DOD SPACECRAFT

OPTION NUMBER	FUNCTION TITLE INSTALL SPACECRAFT EQUIPMENT	FLOW BLOCK NO. 2.2.1.2.b

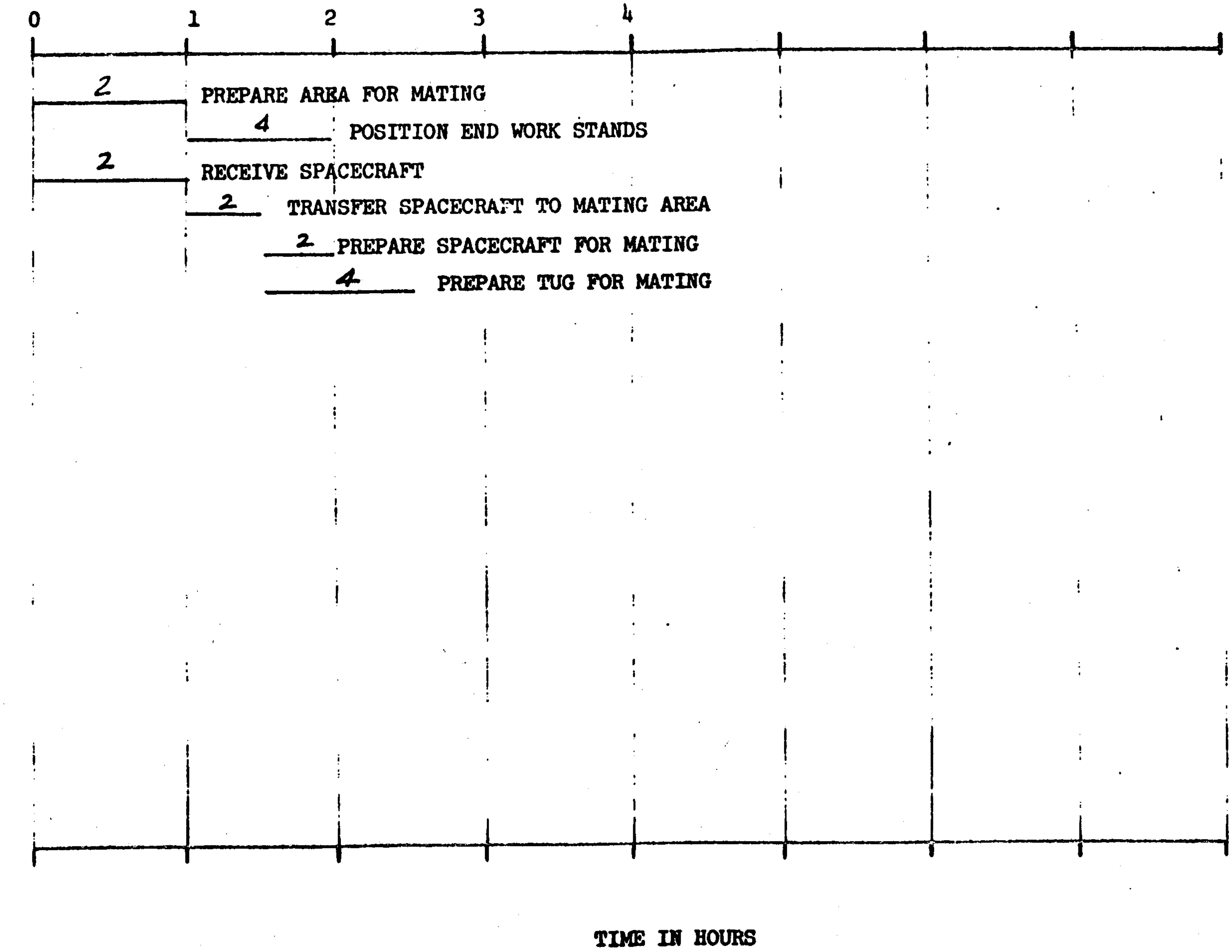


NOTE: NASA PAYLOAD

OPTION NUMBER	FUNCTION TITLE VERIFY TUG-TO-SPACECRAFT EQUIP. INTERFACES	FLOW BLOCK NO. 2.2.1.3

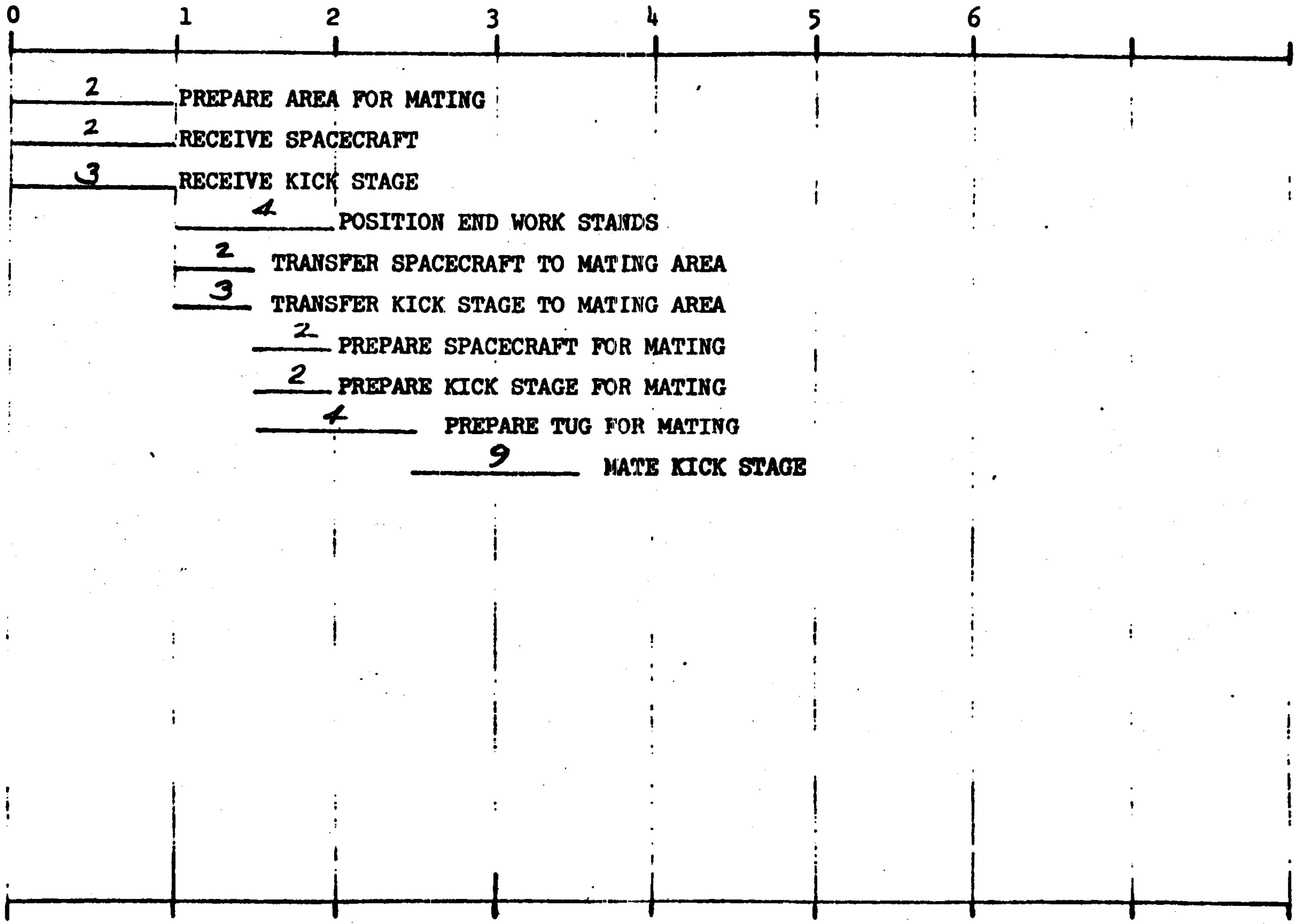


OPTION NUMBER	FUNCTION TITLE PREPARE TUG FOR SPACECRAFT	FLOW BLOCK NO. 2.2.2.a



NOTE: NO KICK STAGE

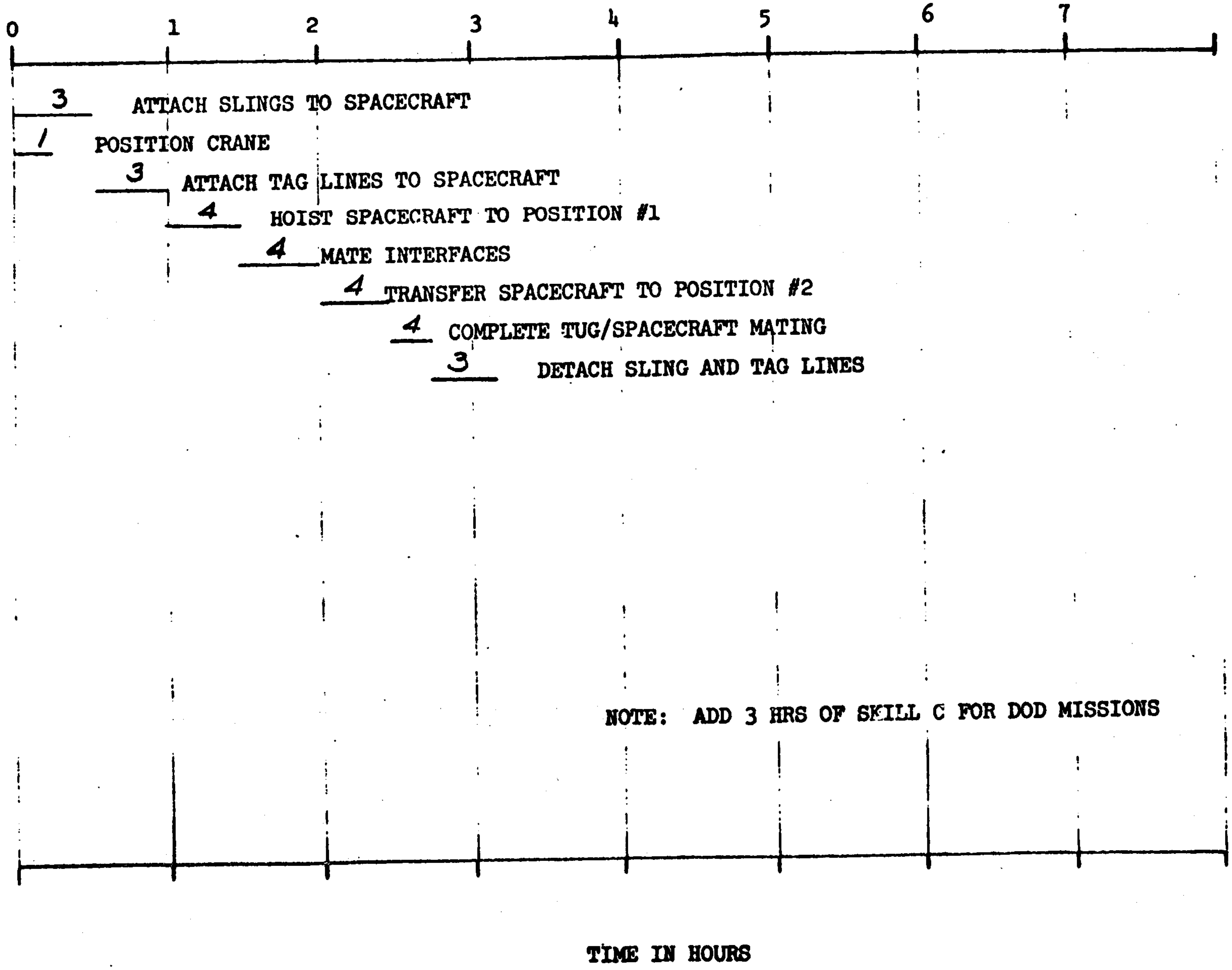
OPTION NUMBER	FUNCTION TITLE	PREPARE TUG FOR SPACECRAFT	FLOW BLOCK NO.	2.2.2.b



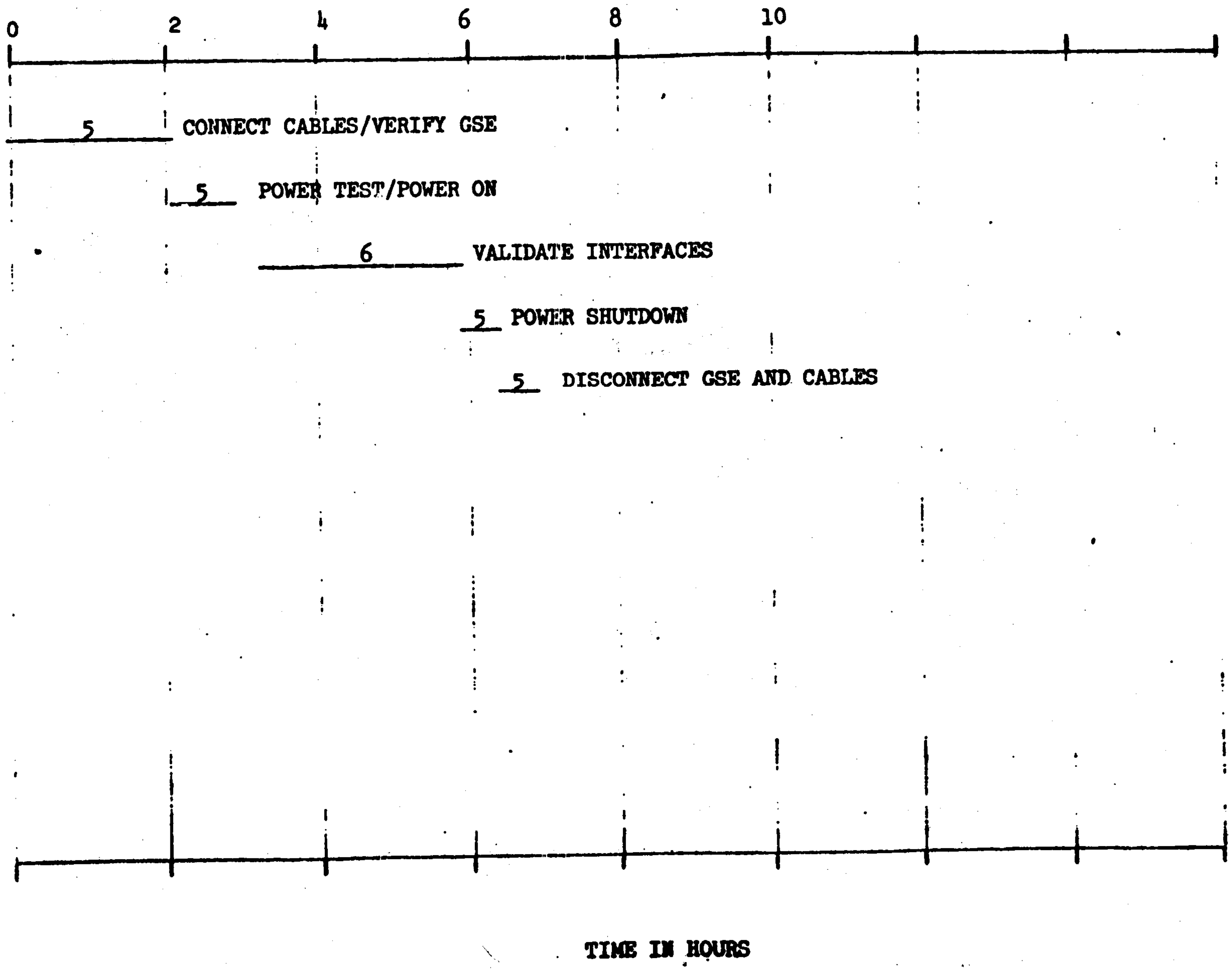
TIME IN HOURS

NOTE: KICK STAGE INVOLVED

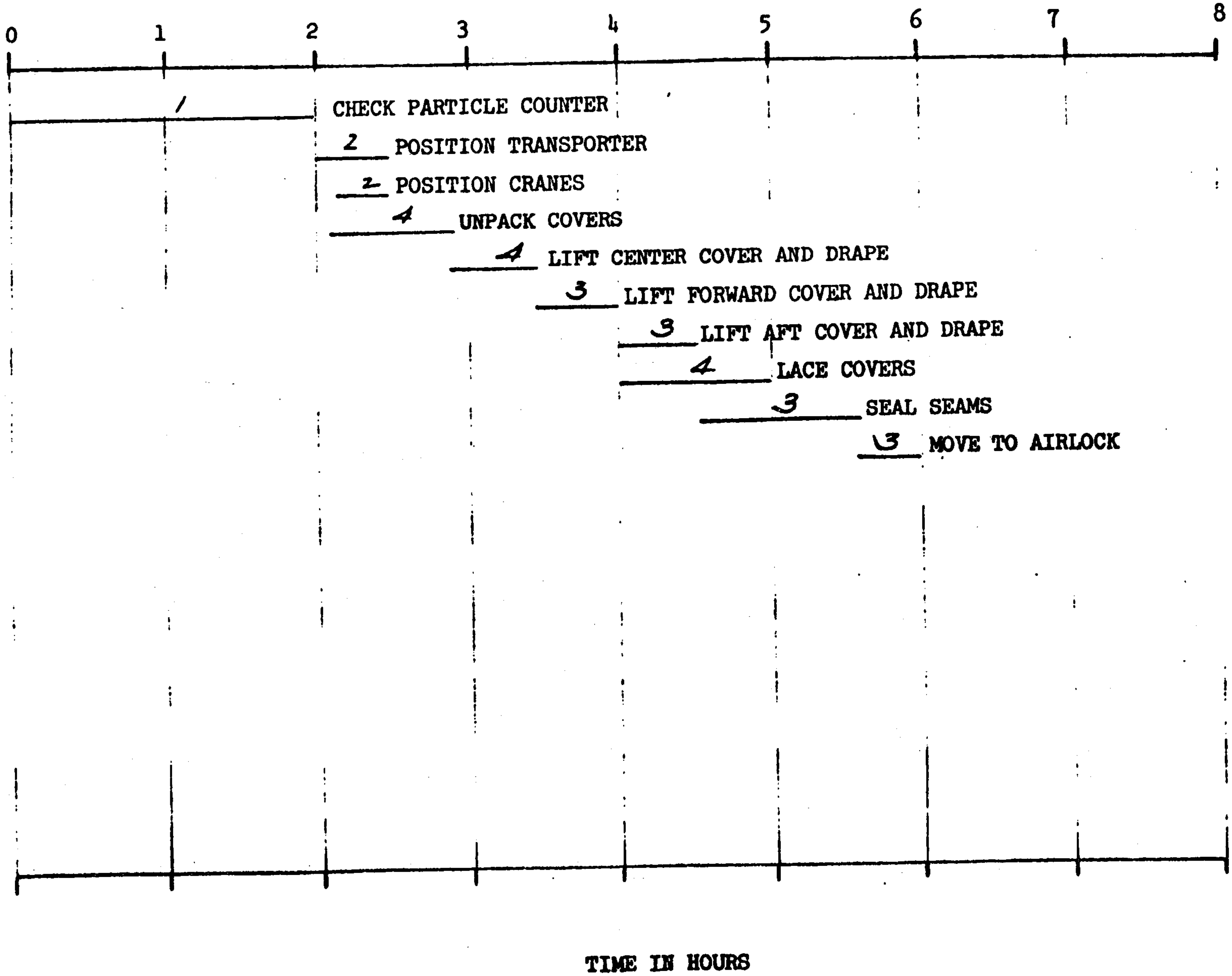
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
	MATE TUG AND SPACECRAFT	2.2.3



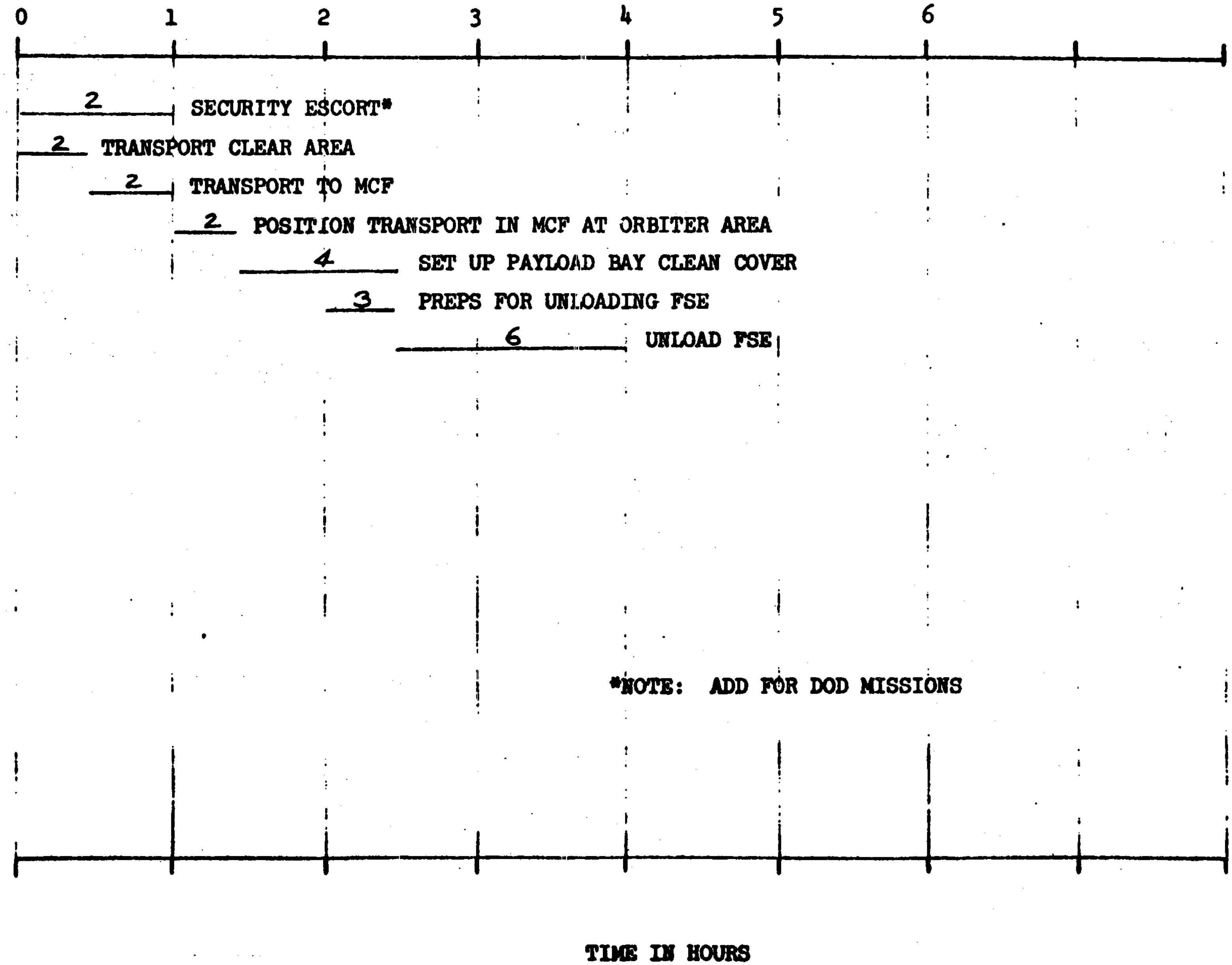
OPTION NUMBER	FUNCTION TITLE VERIFY TUG-TO-SPACECRAFT INTERFACES	FLOW BLOCK NO. 2.2.4



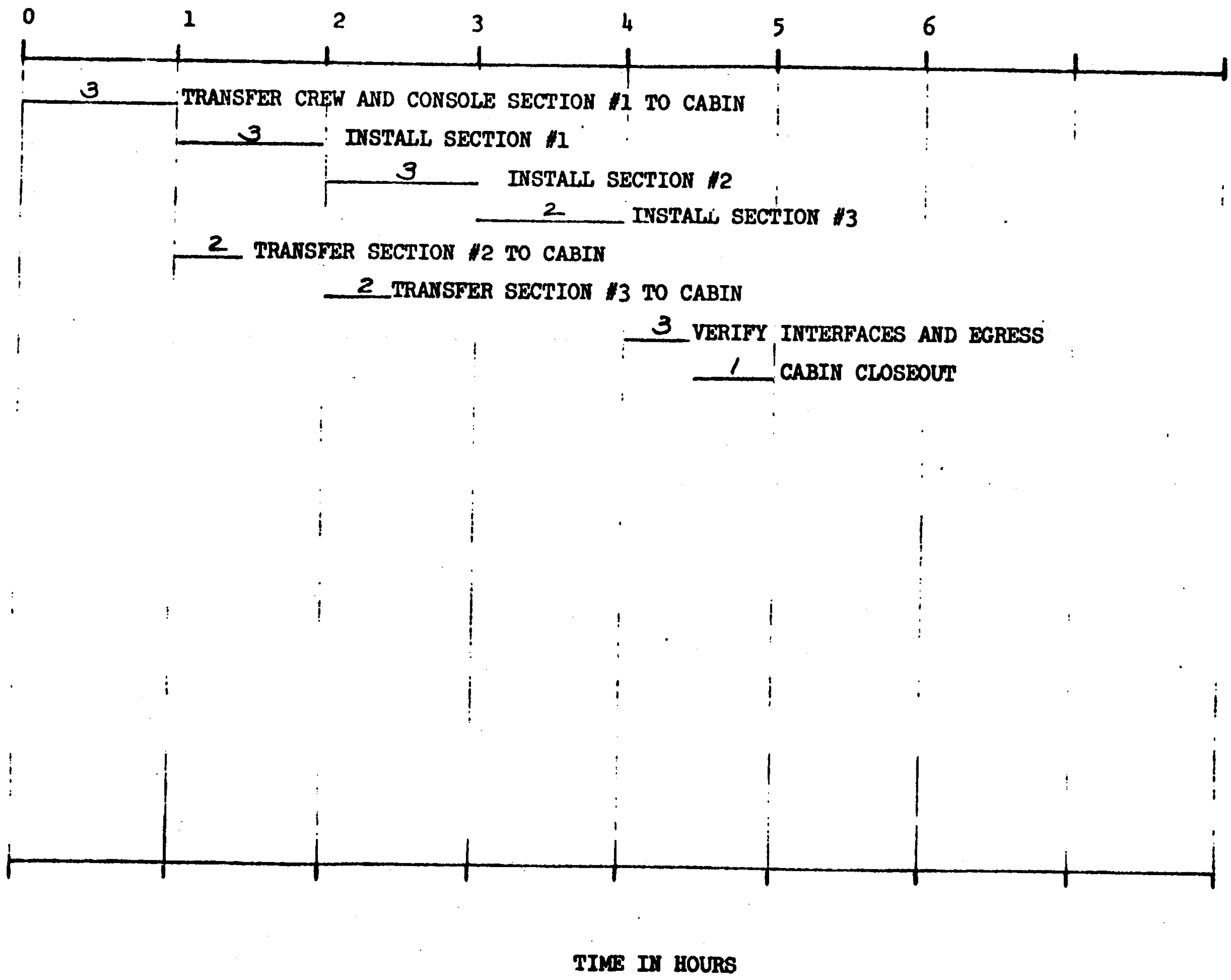
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
	VERIFY CLEANLINESS	2.2.5



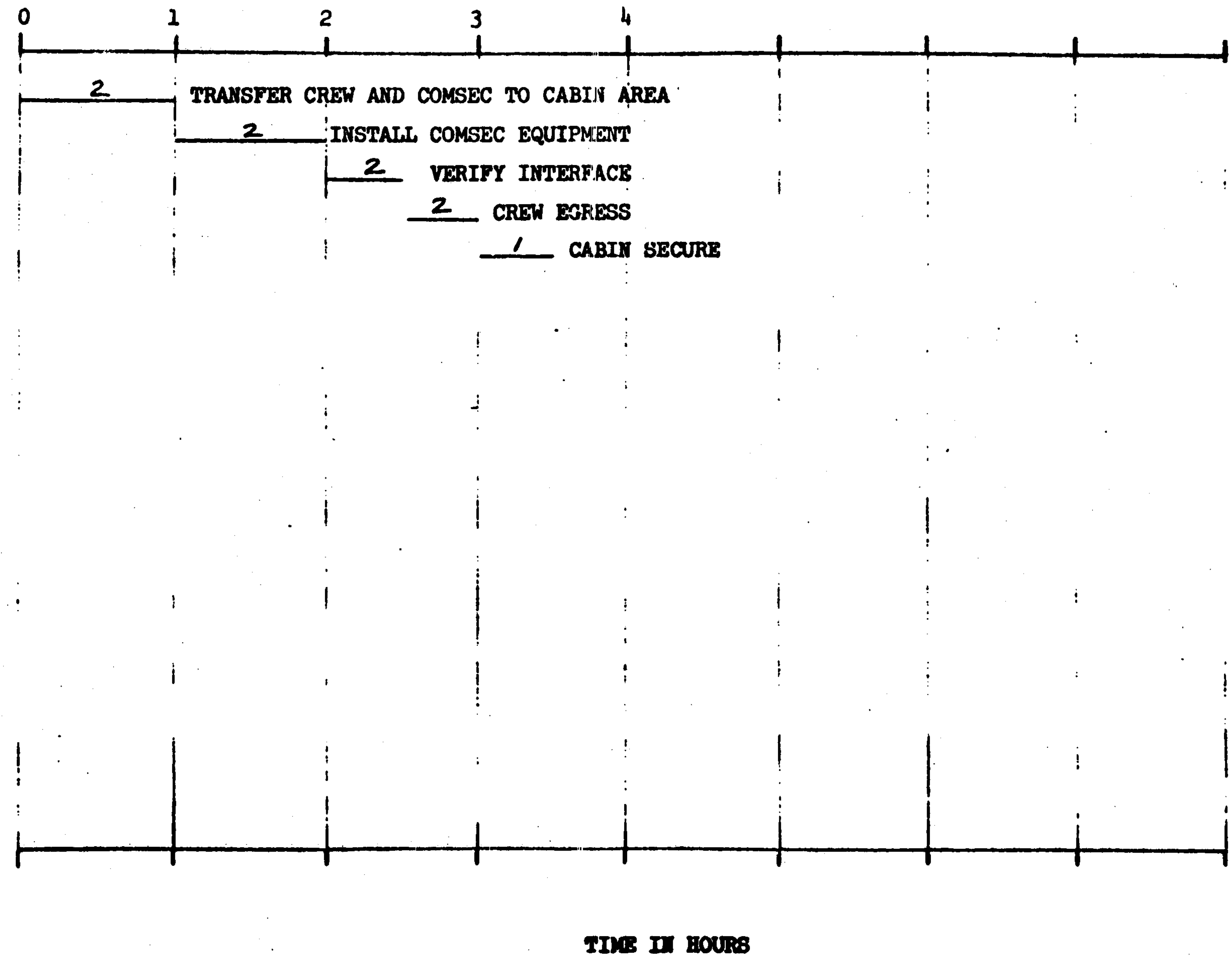
OPTION NUMBER	FUNCTION TITLE	TRANSFER FSE TO MCF	FLOW BLOCK NO.	2.3.1



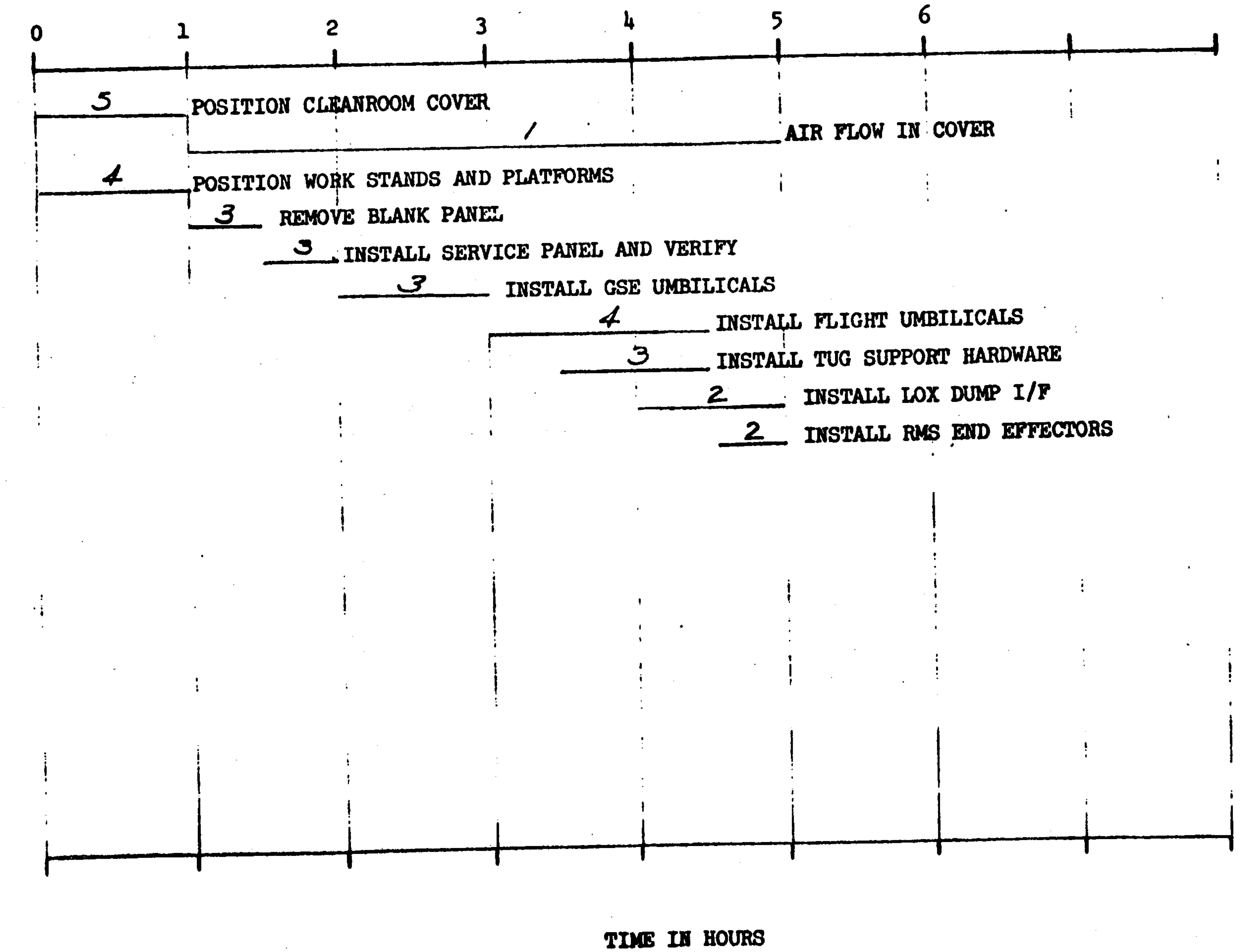
OPTION NUMBER	FUNCTION TITLE INSTALL FSE IN CABIN (CONSOLE)	FLOW BLOCK NO. 2.3.2.1.a



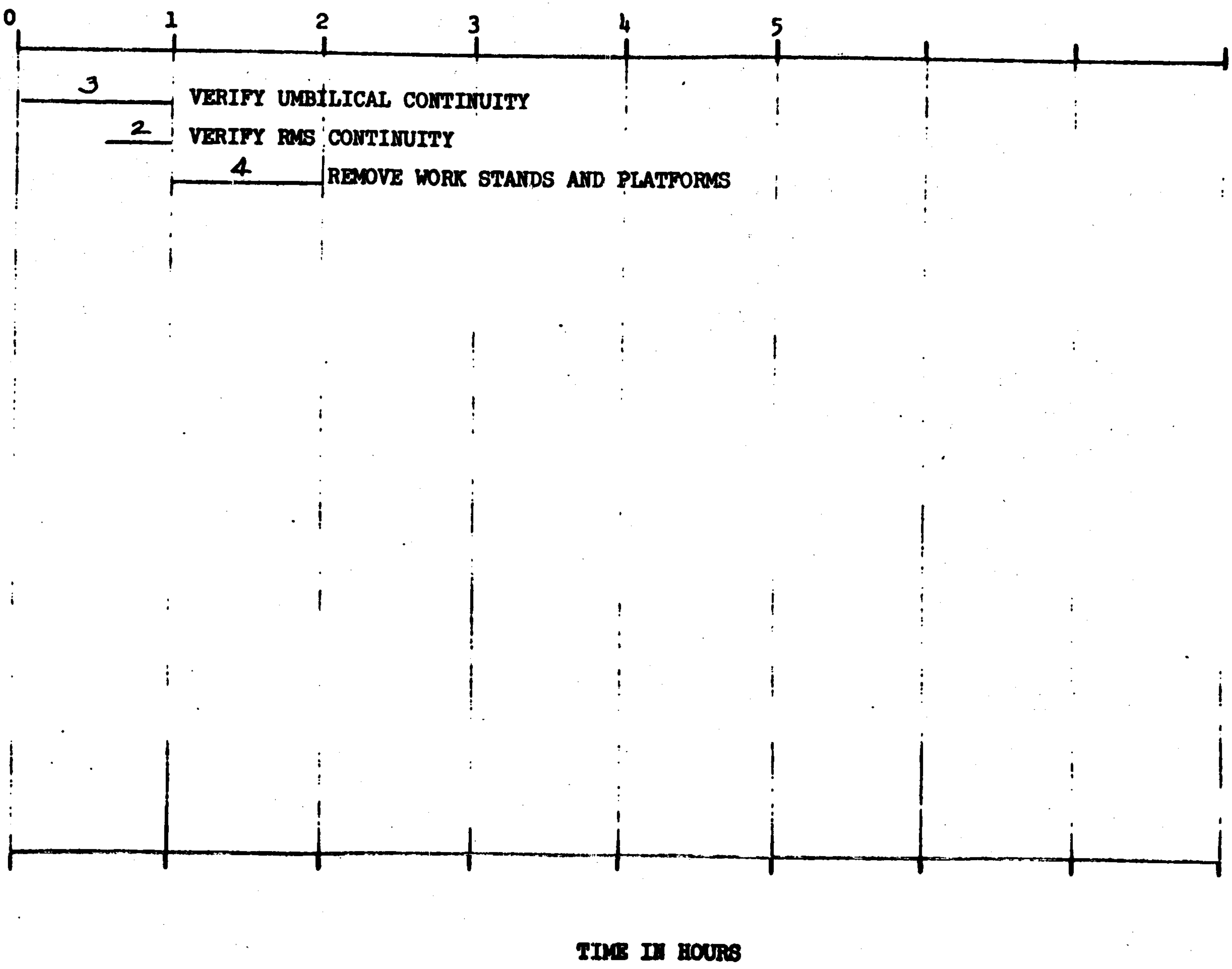
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
	INSTALL FSE IN CABIN (COMSEC)	2.3.2.1.b



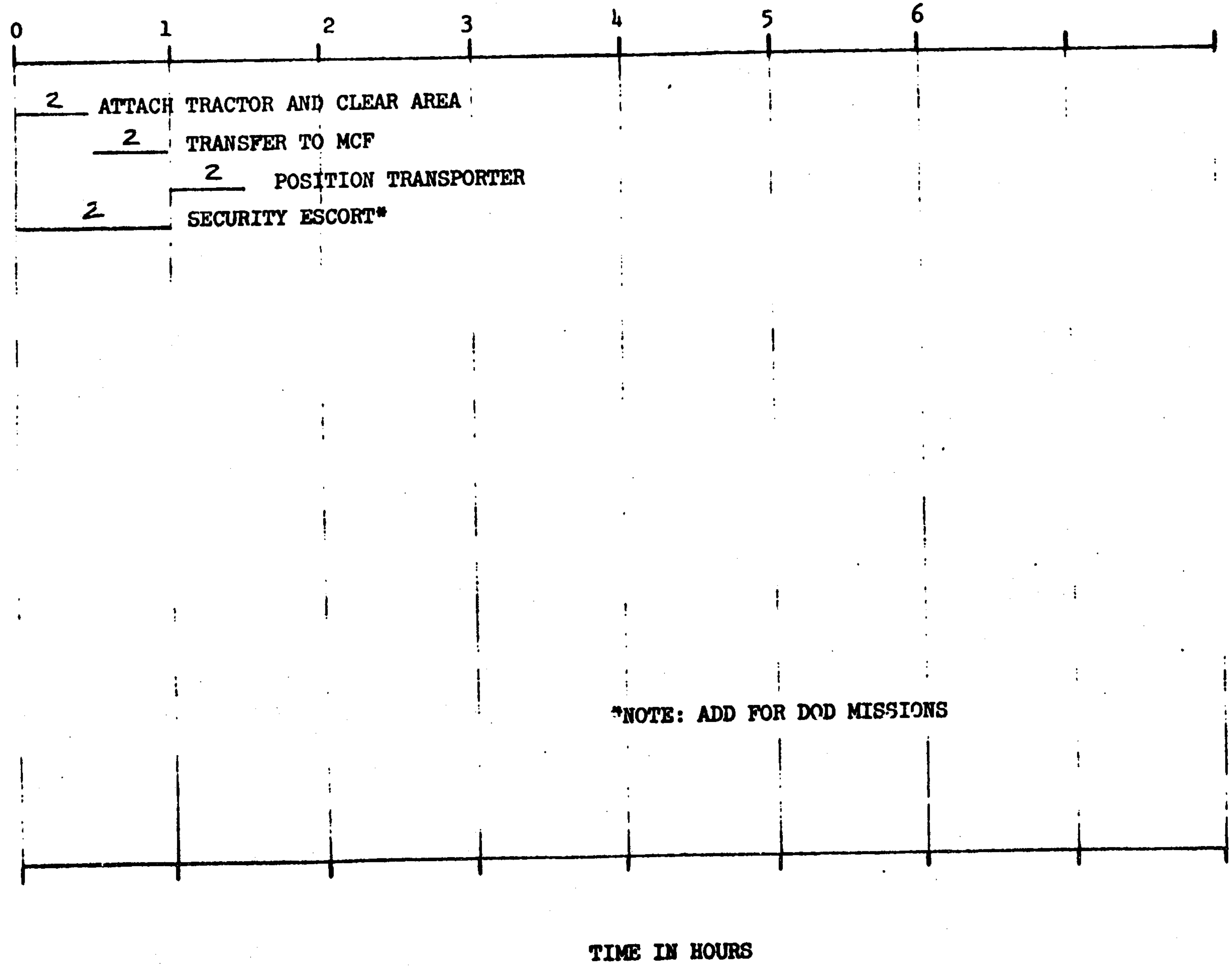
OPTION NUMBER	FUNCTION TITLE INSTALL FSE IN PAYLOAD BAY	FLOW BLOCK NO. 2.3.2.2



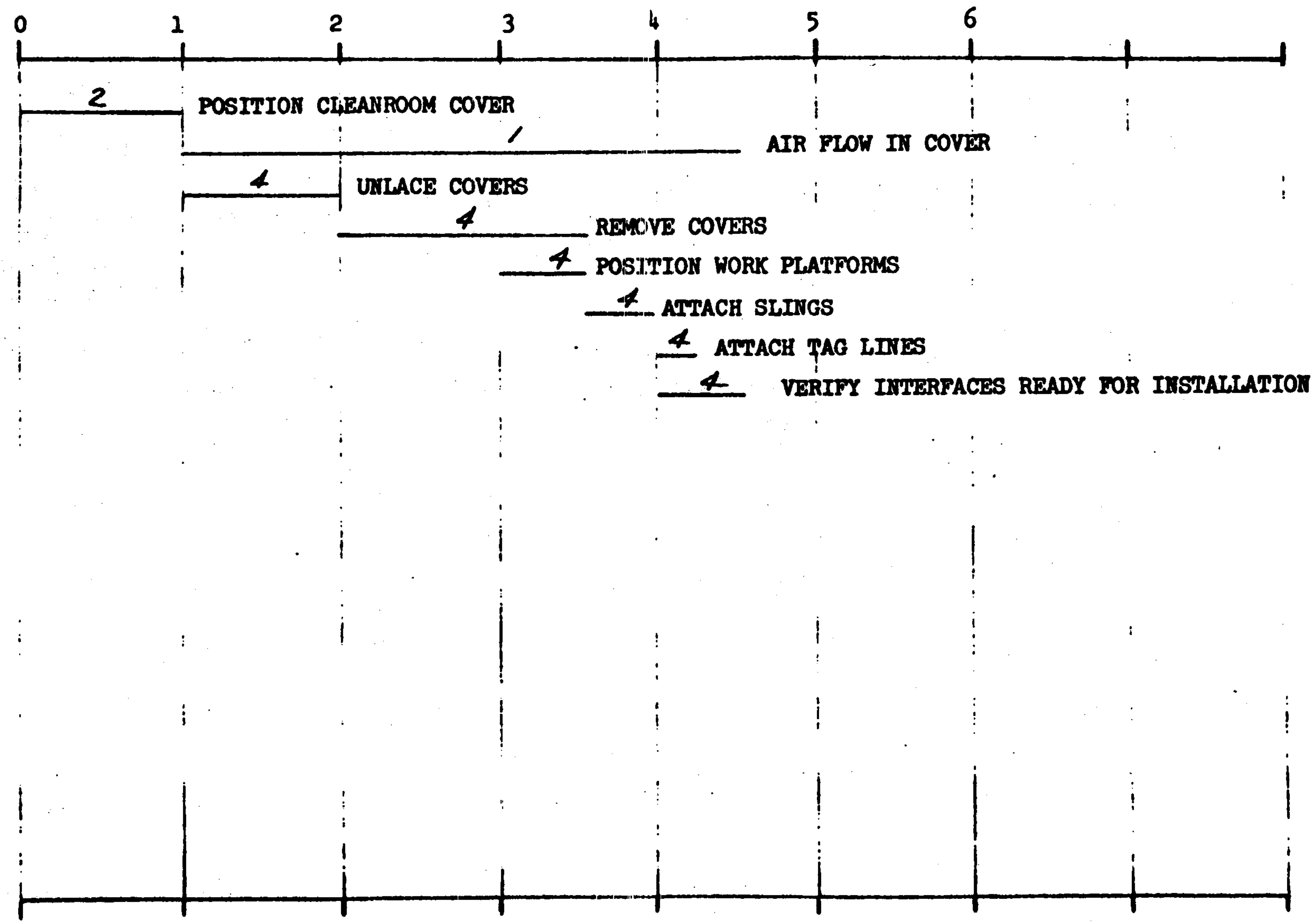
OPTION NUMBER	FUNCTION TITLE VERIFY FSE INTERFACES	FLOW BLOCK NO. 2.3.3



OPTION NUMBER	FUNCTION TITLE TRANSFER PAYLOAD TO MCF	FLOW BLOCK NO. 2.3.4

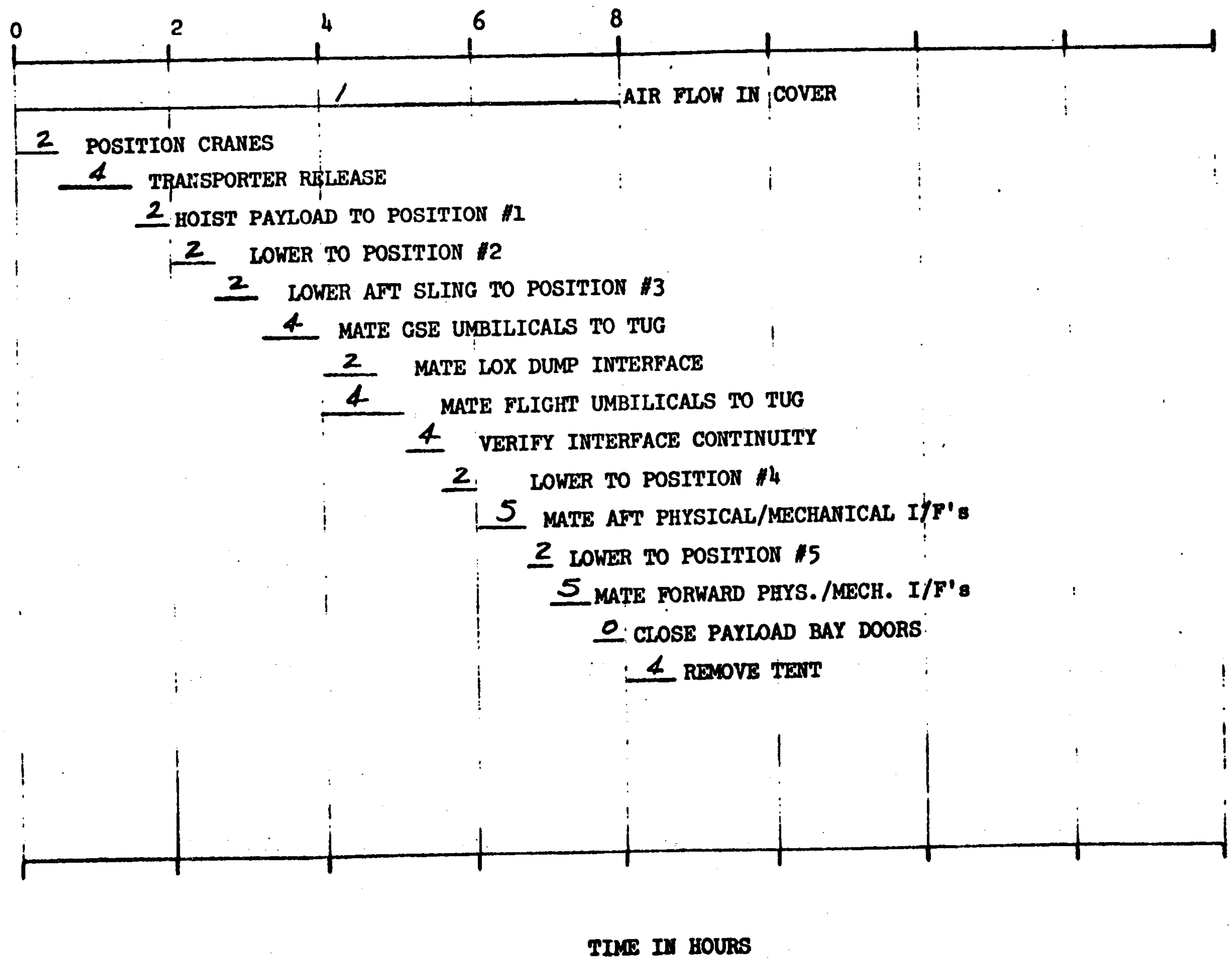


OPTION NUMBER	FUNCTION TITLE PAYLOAD INSTALLATION PREPS	FLOW BLOCK NO. 2.3.6

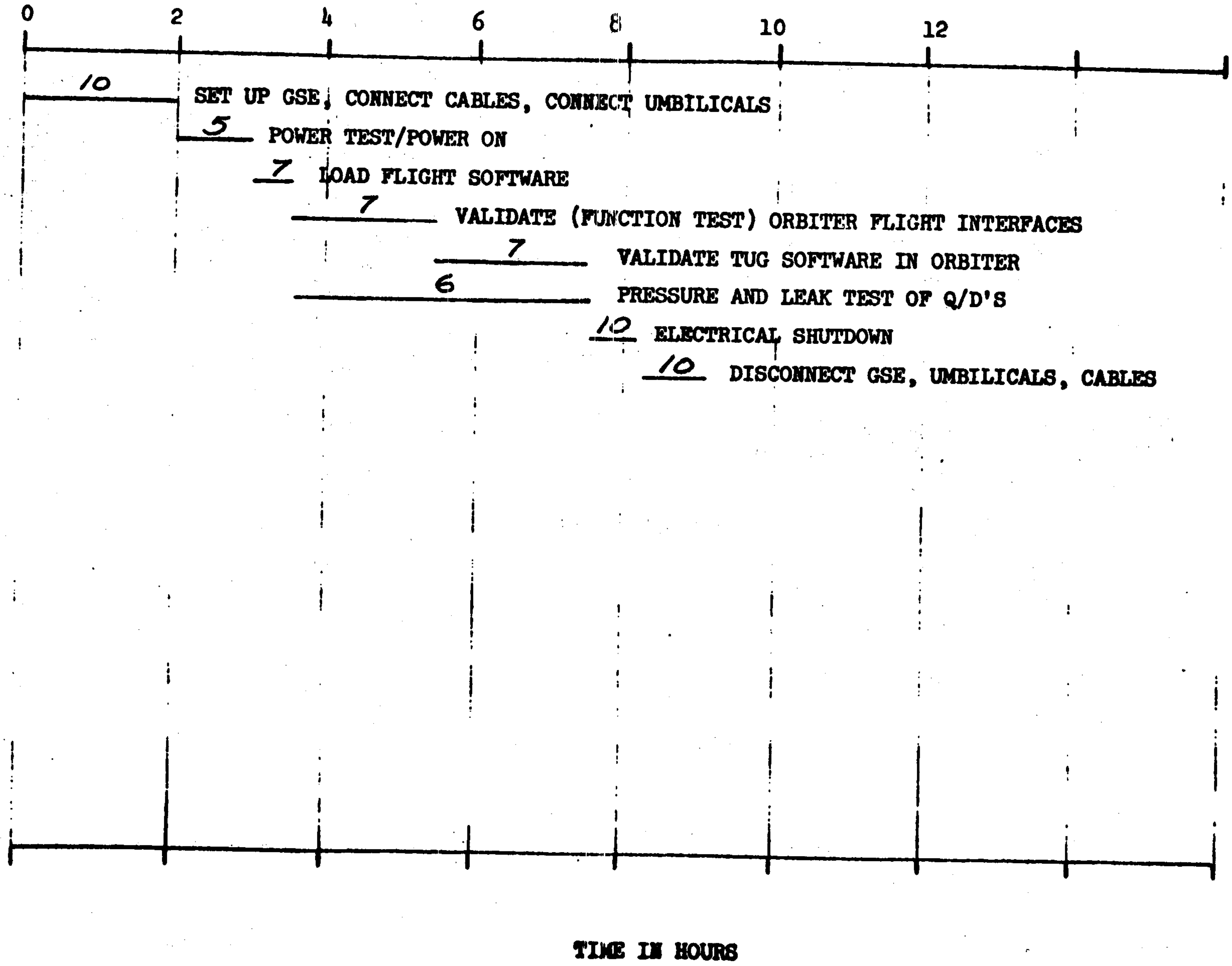


TIME IN HOURS

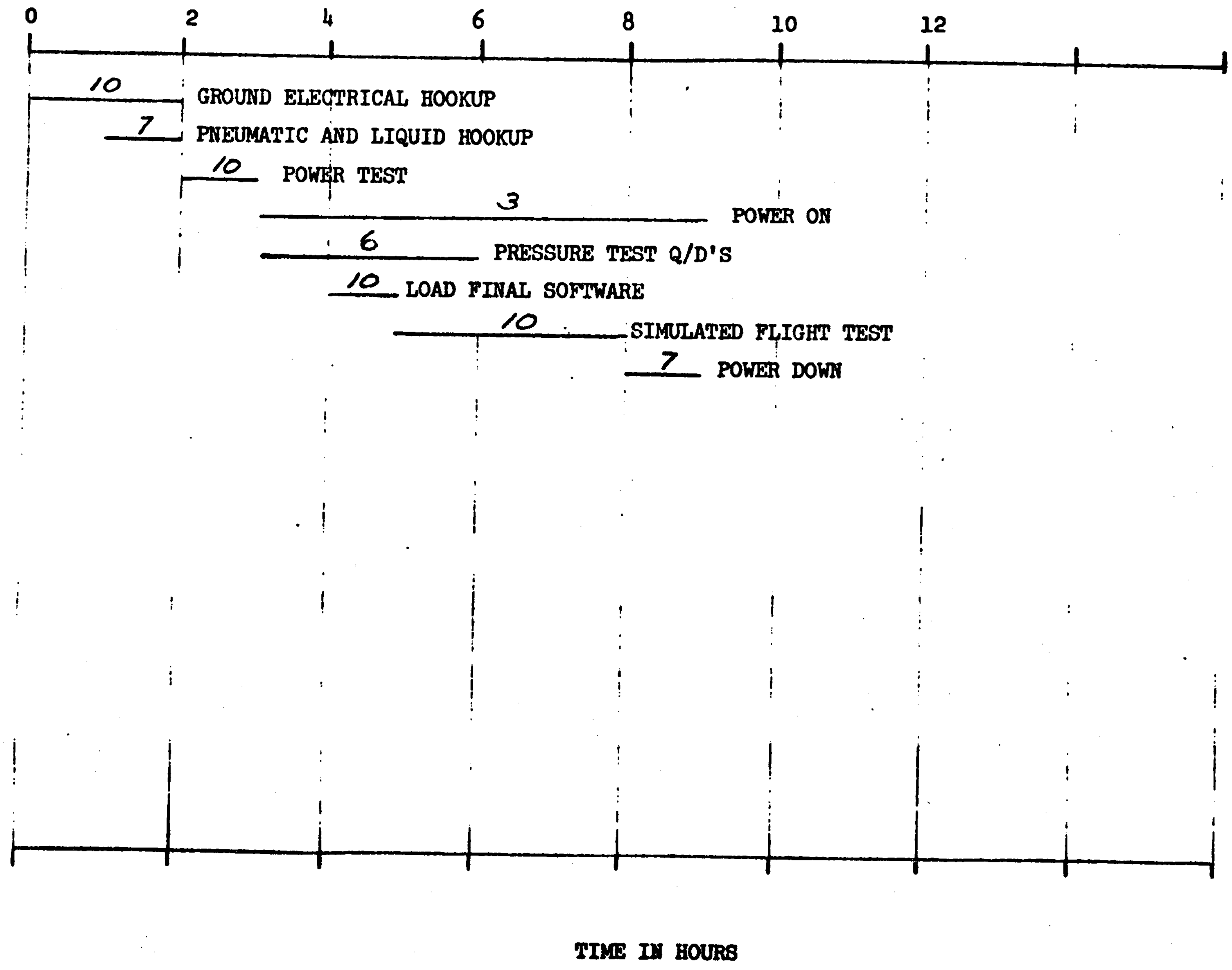
OPTION NUMBER	FUNCTION TITLE PAYLOAD INSTALLATION MCF	FLOW BLOCK NO. 2.3.7



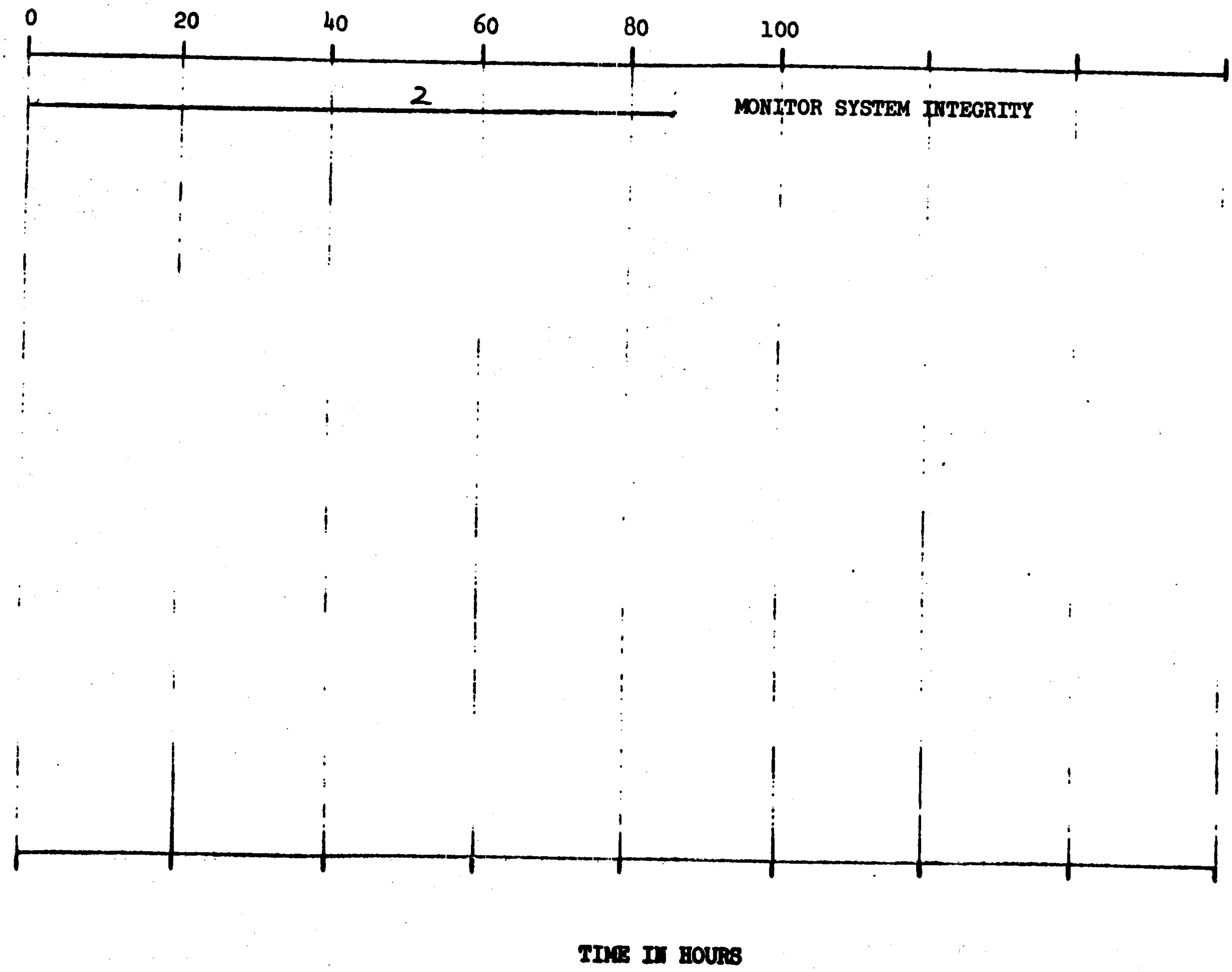
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
	VERIFY PAYLOAD-TO-SHUTTLE INTERFACES	2.3.9



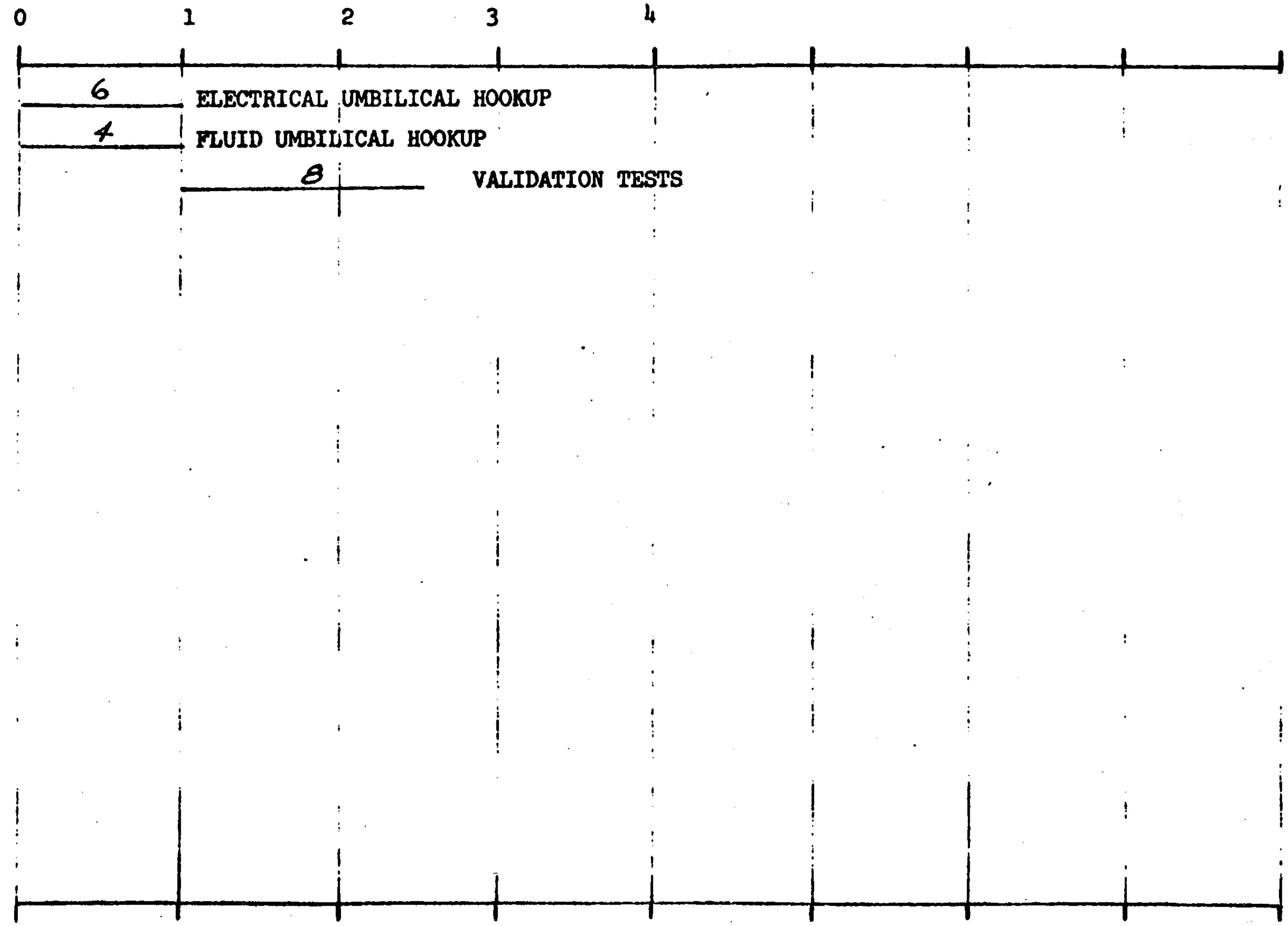
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
	ORBITER/PAYLOAD INTEGRATION SYSTEM TEST	2.4.1



OPTION NUMBER	FUNCTION TITLE MONITOR STORABLE ACPS	FLOW BLOCK NO. 2.4.1.a



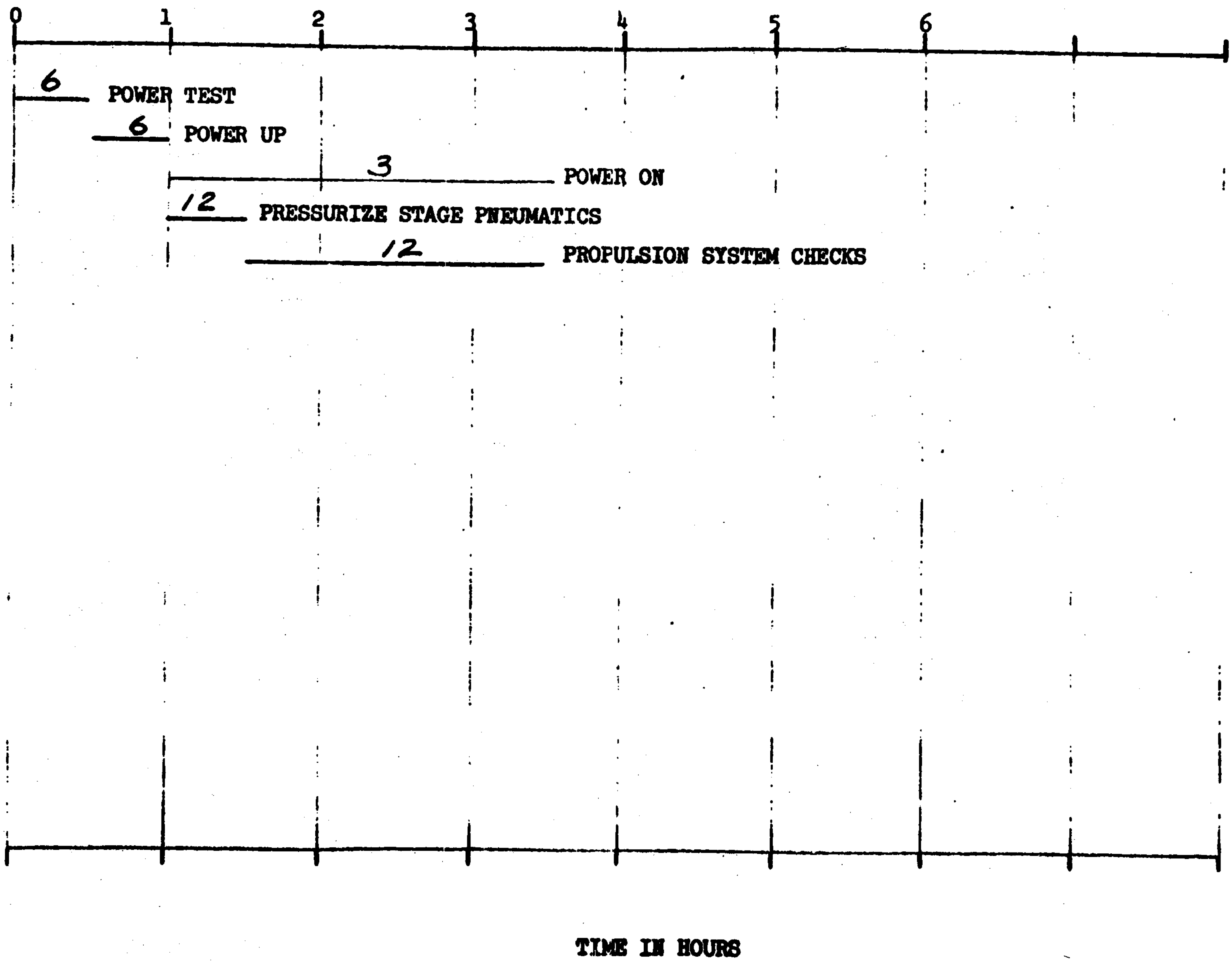
OPTION NUMBER	FUNCTION TITLE TUG SERVICE AT PAD (NON-CRYOS)	FLOW BLOCK NO. 2.4.2.a



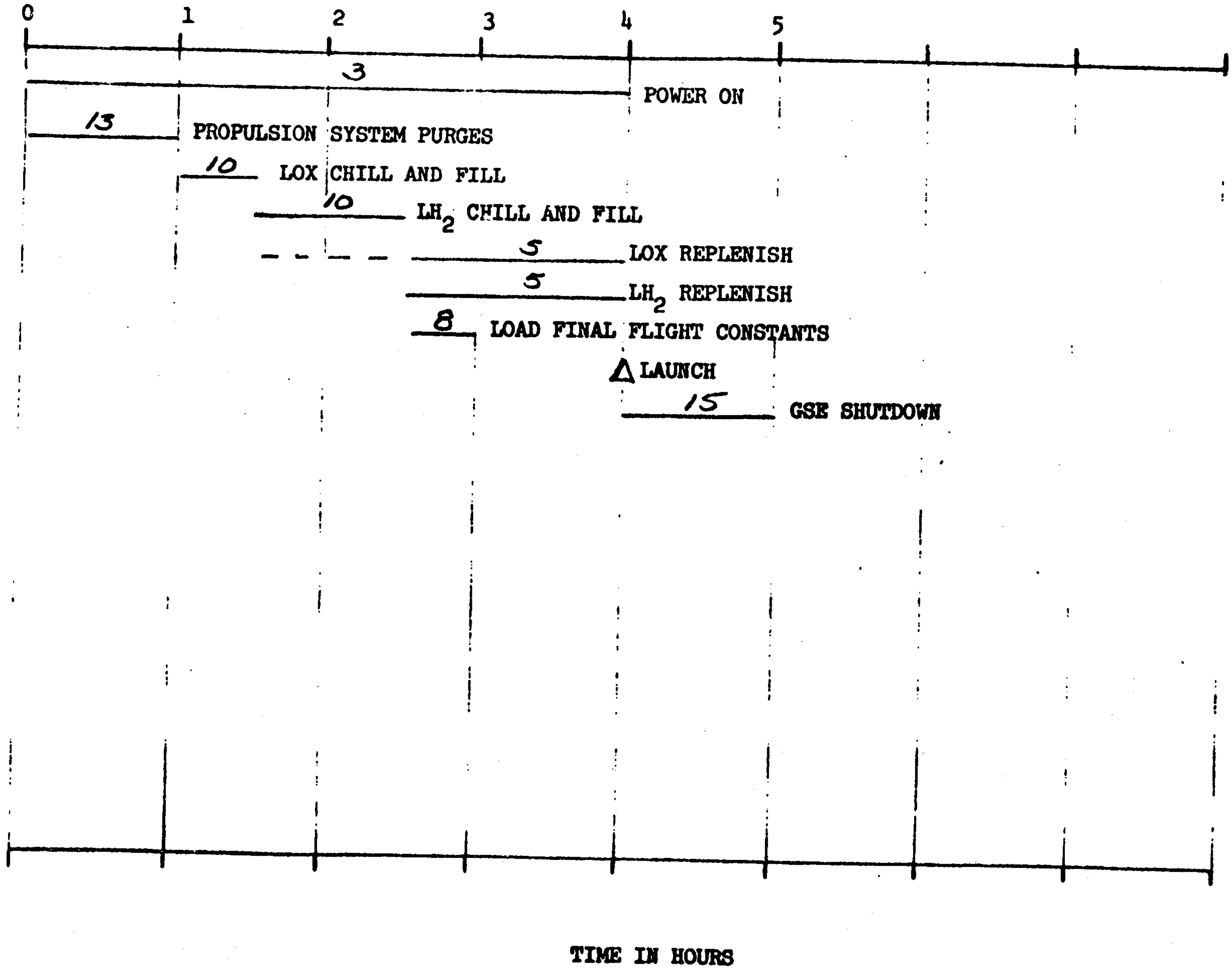
TIME IN HOURS

UMBILICAL HOOKUP

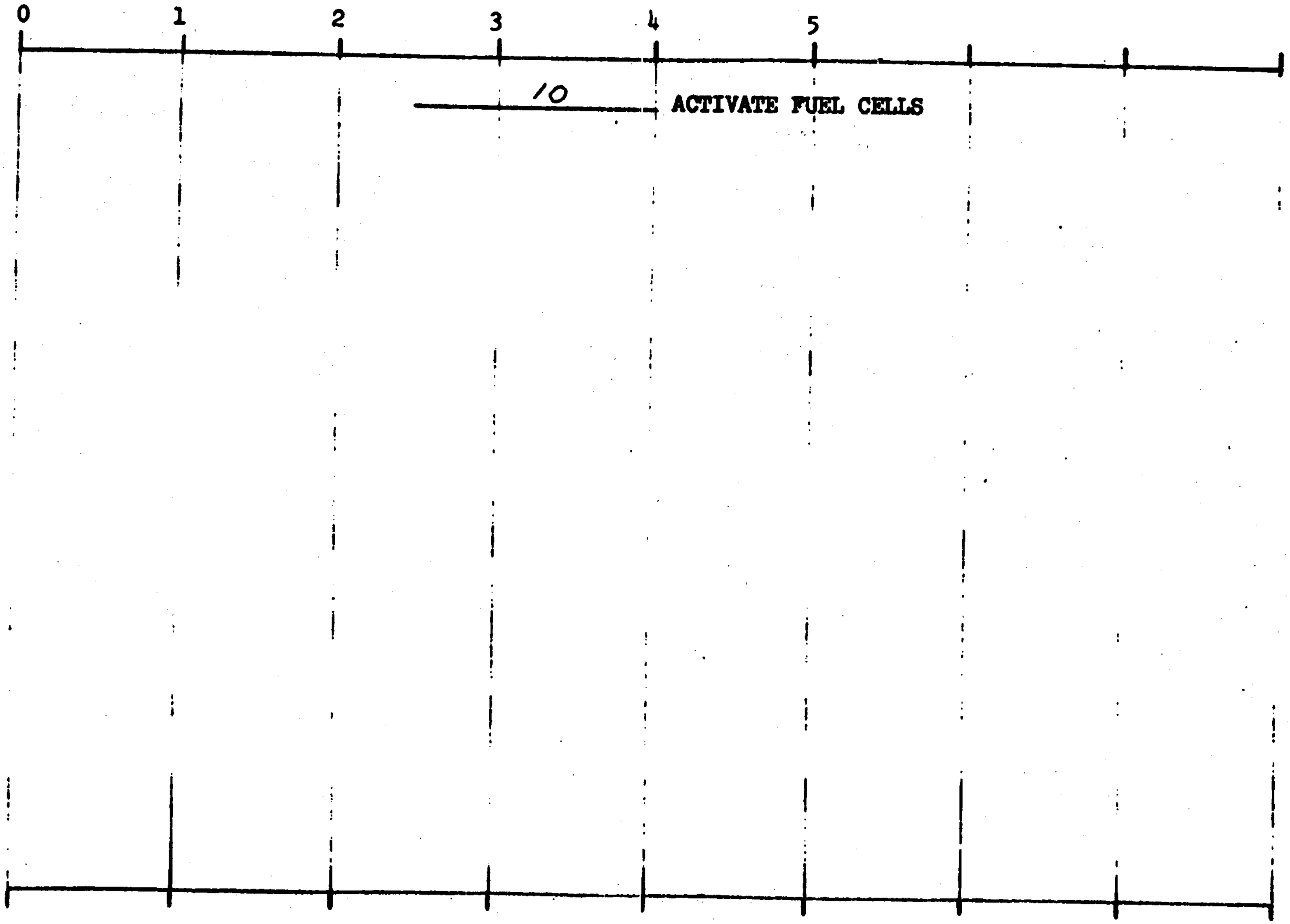
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
	TUG SERVICE AT PAD (NON-CRYO)	2.4.2.b



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
	TUG SERVICE AT PAD (CRYO'S)	2.4.3



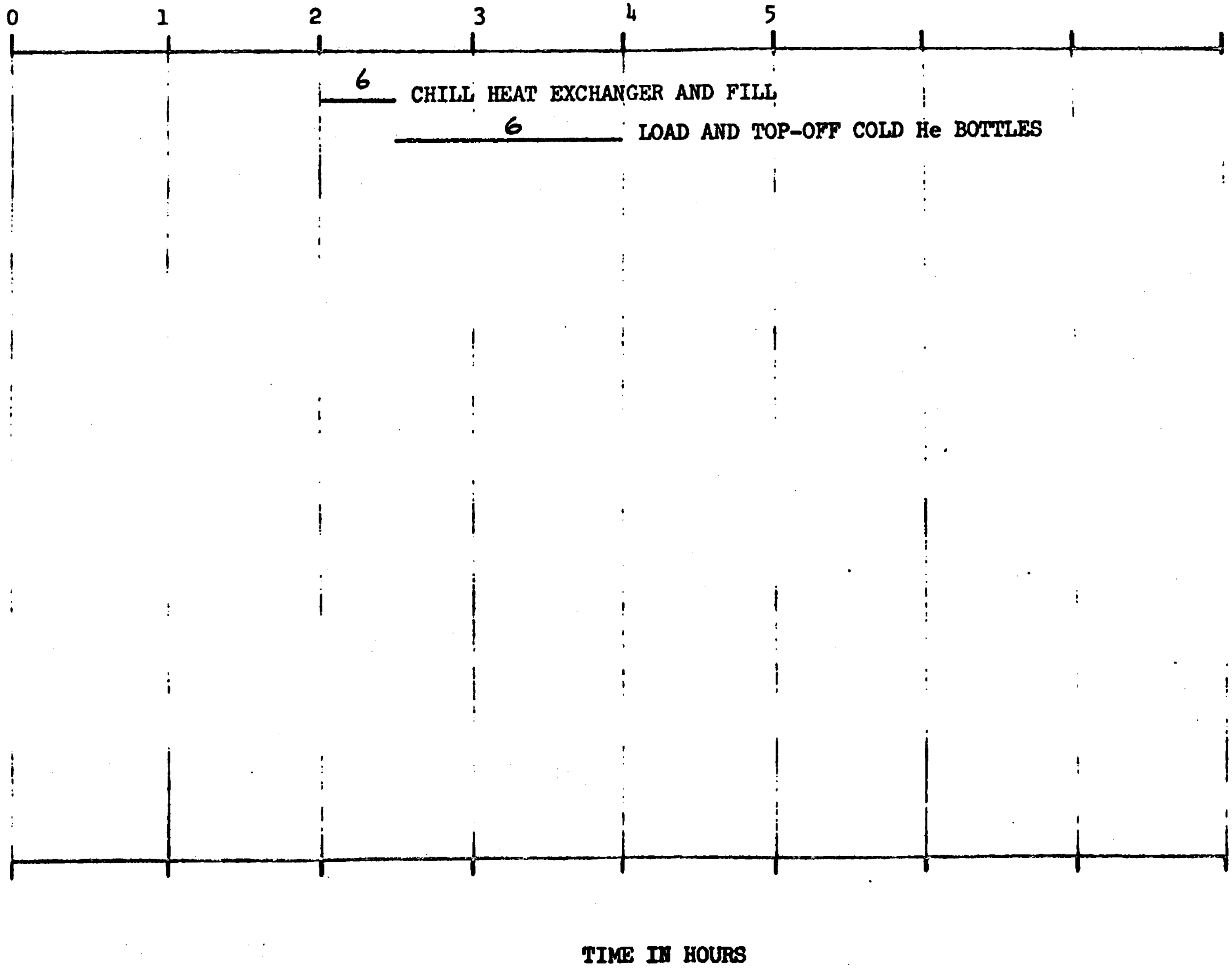
OPTION NUMBER	FUNCTION TITLE TUG SERVICE AT PAD (CRYO'S)*	FLOW BLOCK NO. 2.4.3.a



*FOR FUEL CELLS

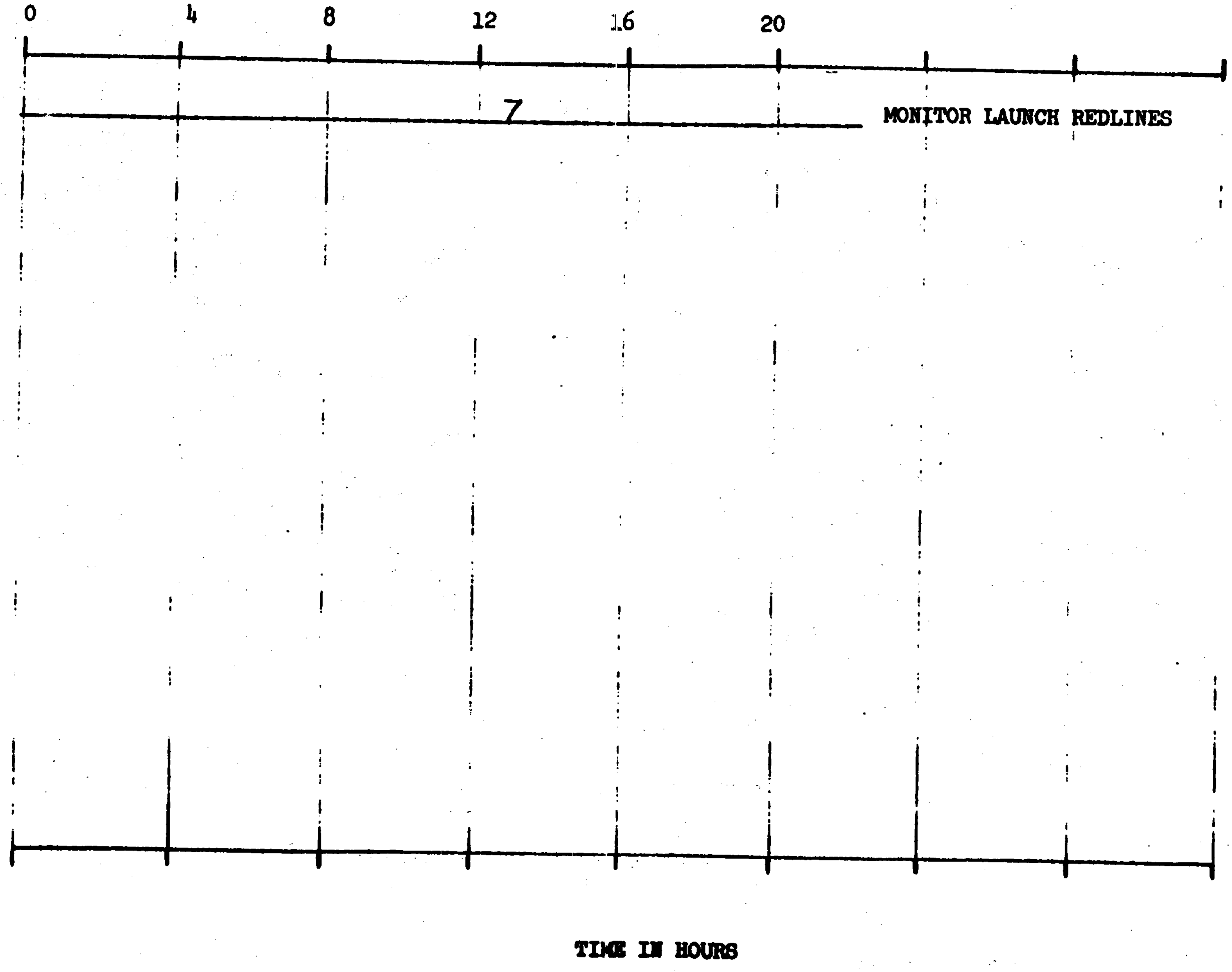
TIME IN HOURS

OPTION NUMBER	FUNCTION TITLE TUG SERVICE AT PAD (CRYO'S)*	FLOW BLOCK NO. 2.4.3.b

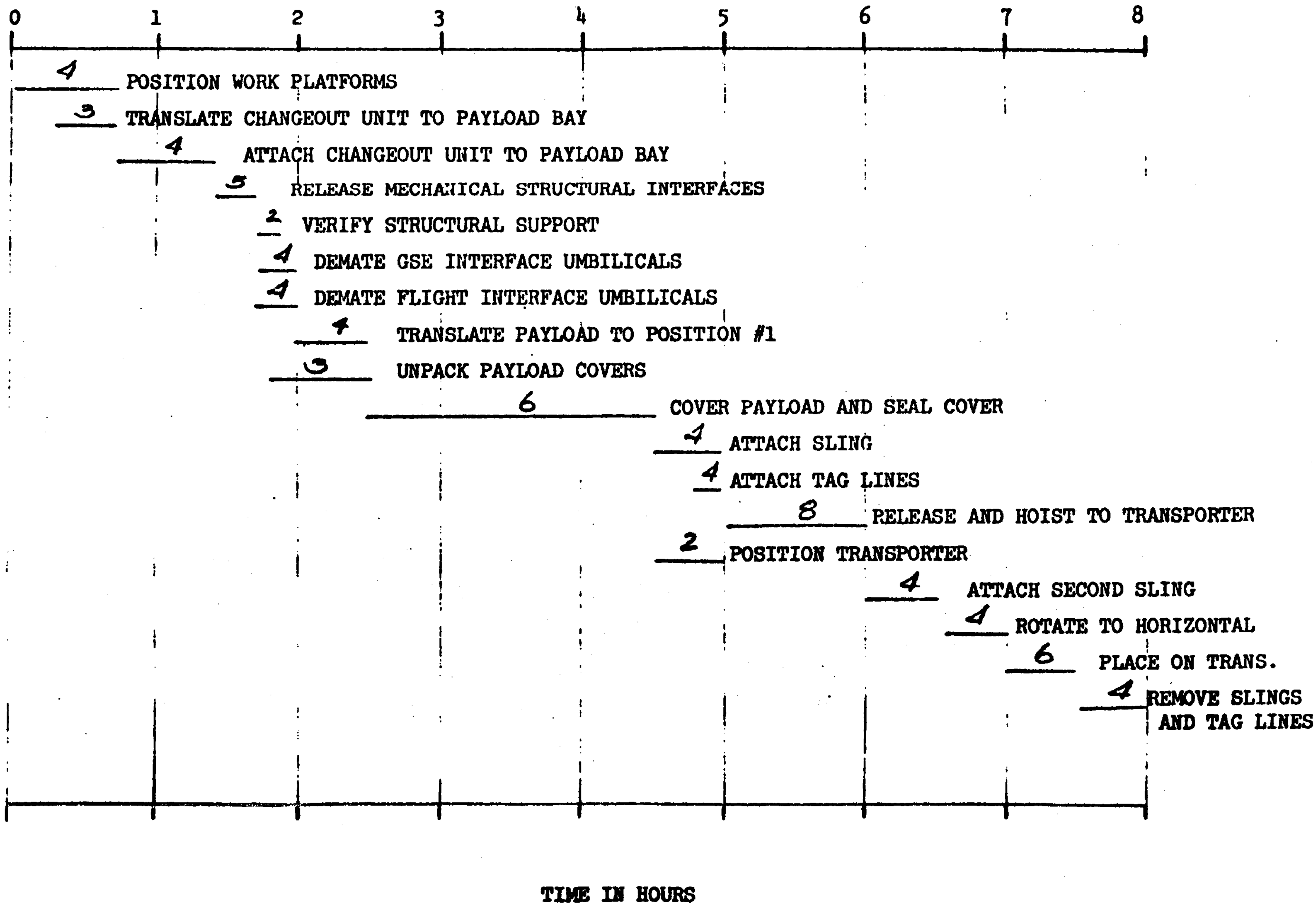


*FOR COLD HE PRESS. SYSTEM

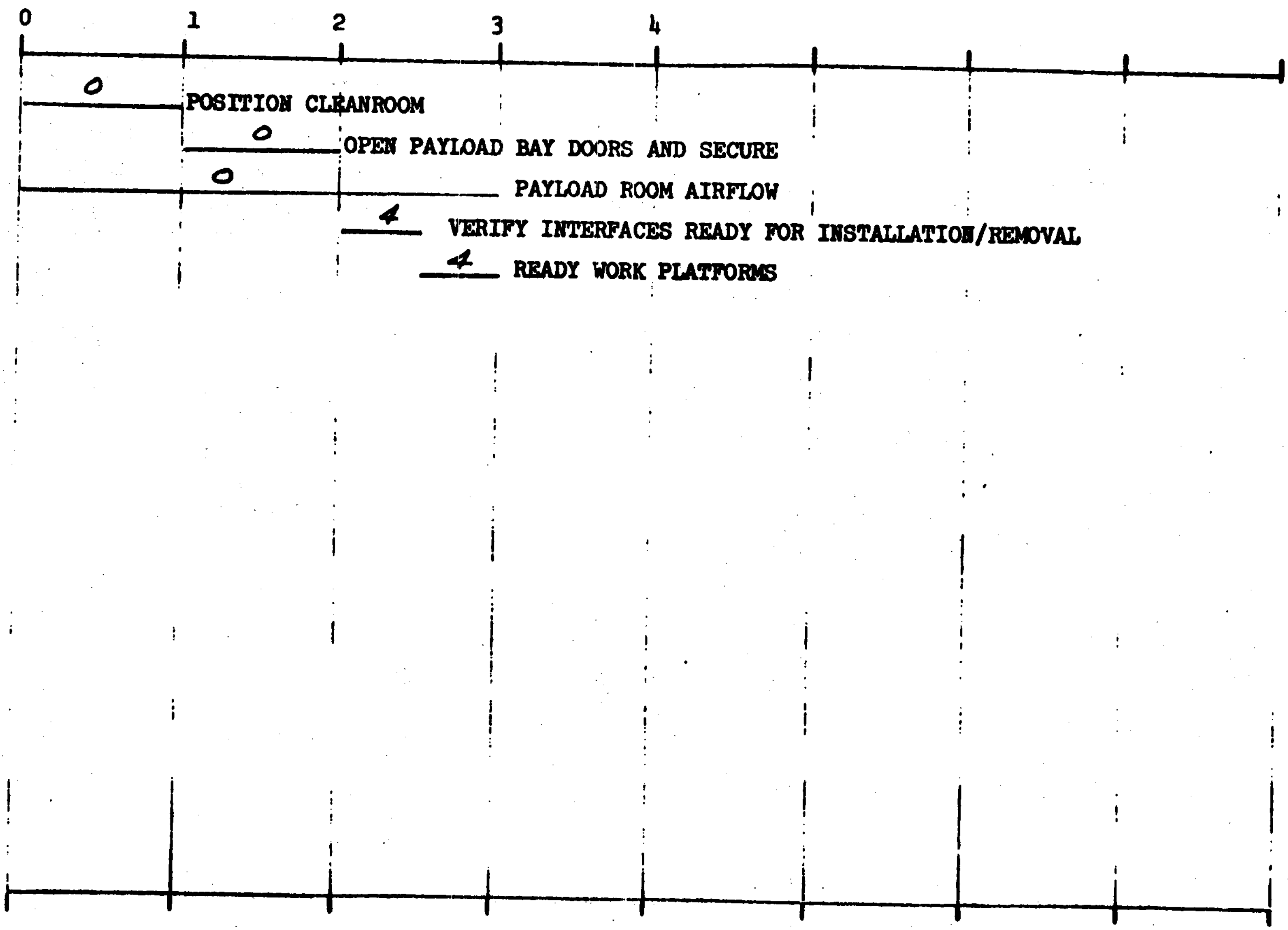
OPTION NUMBER	FUNCTION TITLE SUBSYSTEM MONITORING AT PAD	FLOW BLOCK NO. 2.4.4



OPTION NUMBER	FUNCTION TITLE	REMOVE PAYLOAD (PAD)	FLOW BLOCK NO.	2.4.5



OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
	PAYLOAD INSTALLATION OR REMOVAL PREPS (PAD)	2.4.6



TIME IN HOURS

OPTION NUMBER	FUNCTION TITLE	PAYLOAD INSTALLATION (PAD)	FLOW BLOCK NO.	2.4.7

0 2 4 6 8

4 TRANSLATE PAYLOAD TO PAYLOAD BAY (POSITION #3)

4 MATE GSE UMBILICALS TO TUG

2 MATE LOX DUMP INTERFACE

4 MATE FLIGHT UMBILICALS

4 VERIFY INTERFACE CONTINUITY

3 TRANSLATE TO INSTALLATION POSITION

5 MATE AFT PHYSICAL/MECHANICAL I/F'S

5 MATE FORWARD PHYSICAL/MECHANICAL I/F'S

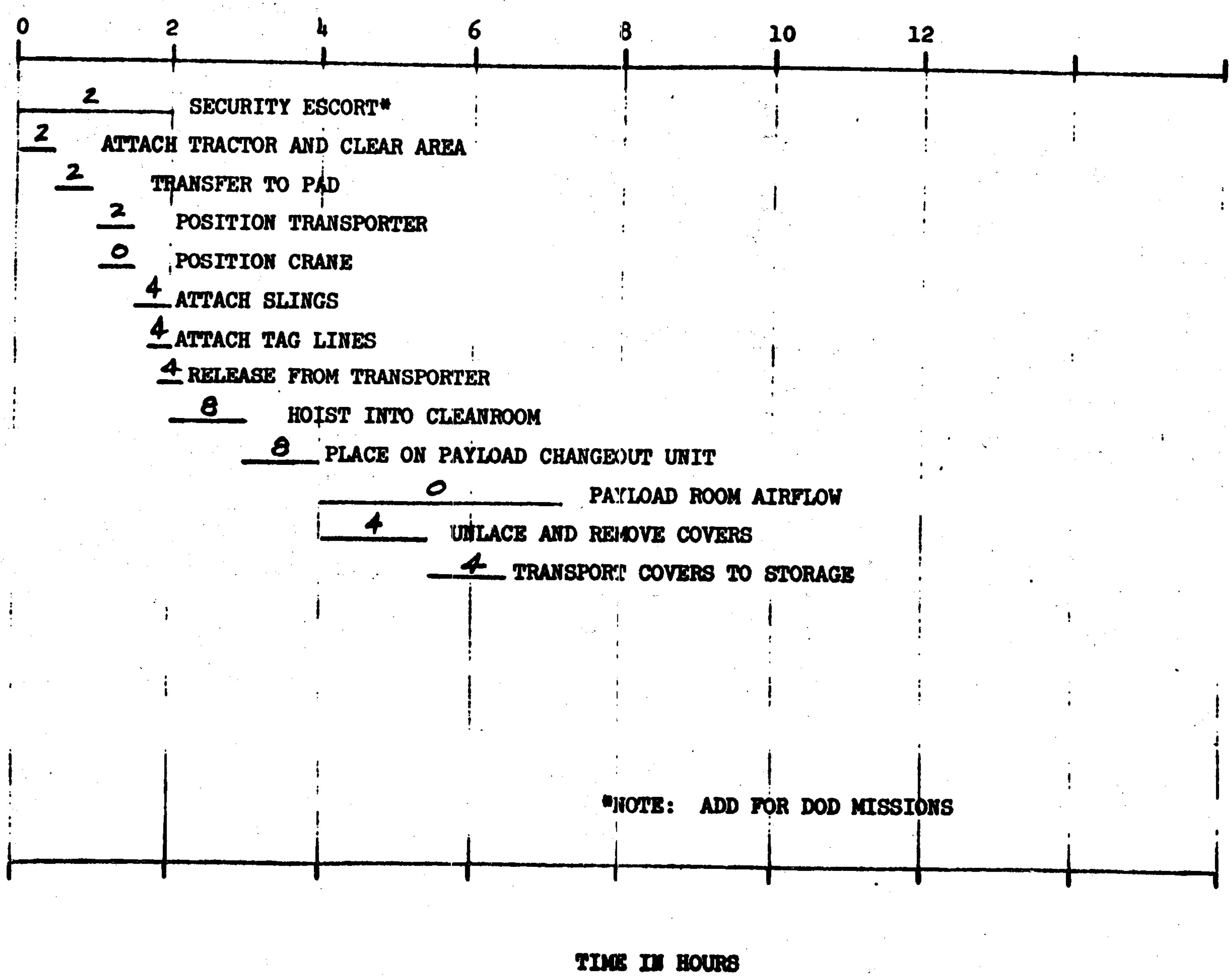
3 VERIFY PHYSICAL I/F'S

3 RELEASE PAYLOAD AND TRANSLATE CHANGEOUT UNIT TO POSITION #1

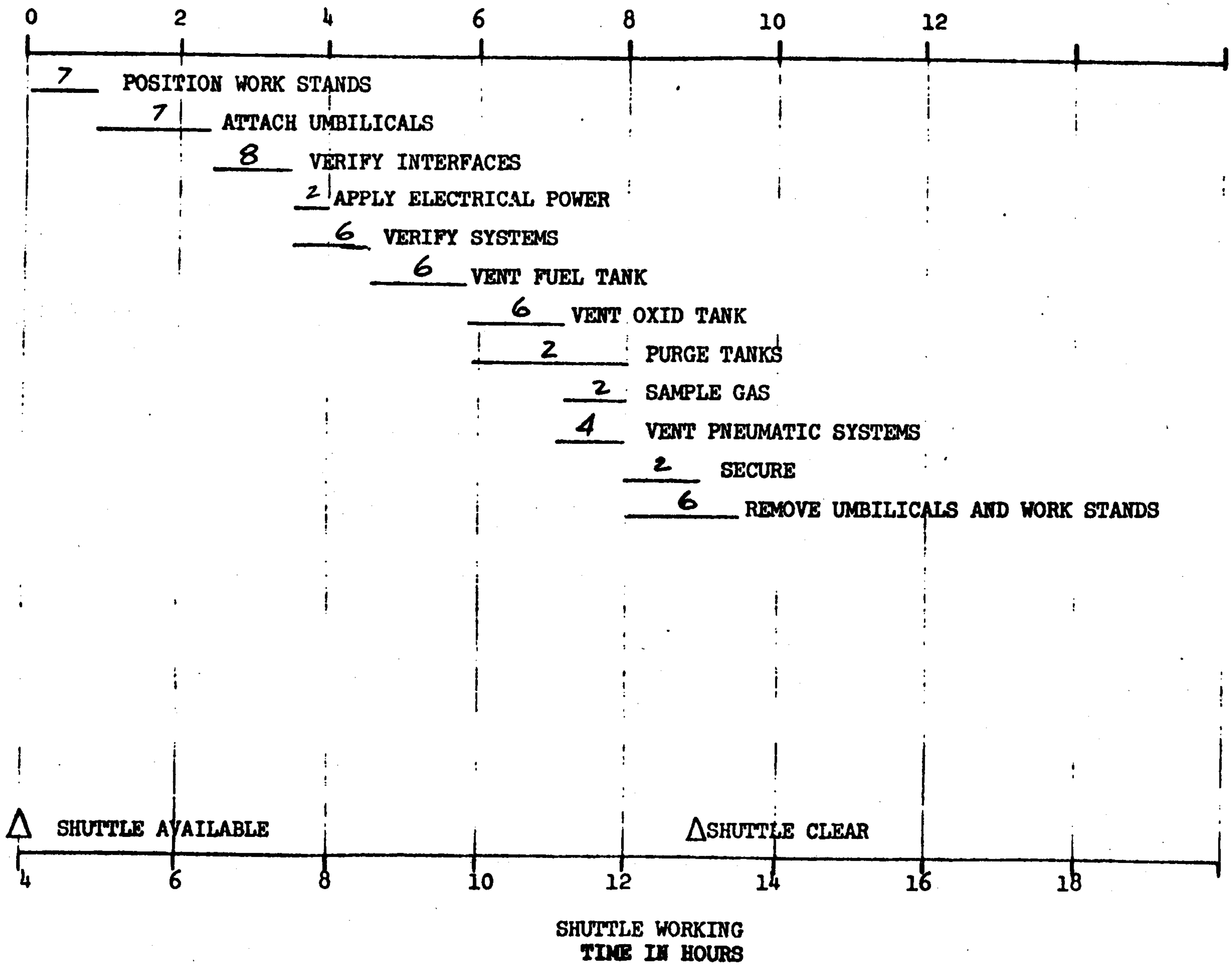
TIME IN HOURS

D-226

OPTION NUMBER	FUNCTION TITLE TRANSFER PAYLOAD TO PAD	FLOW BLOCK NO. 2.4.8



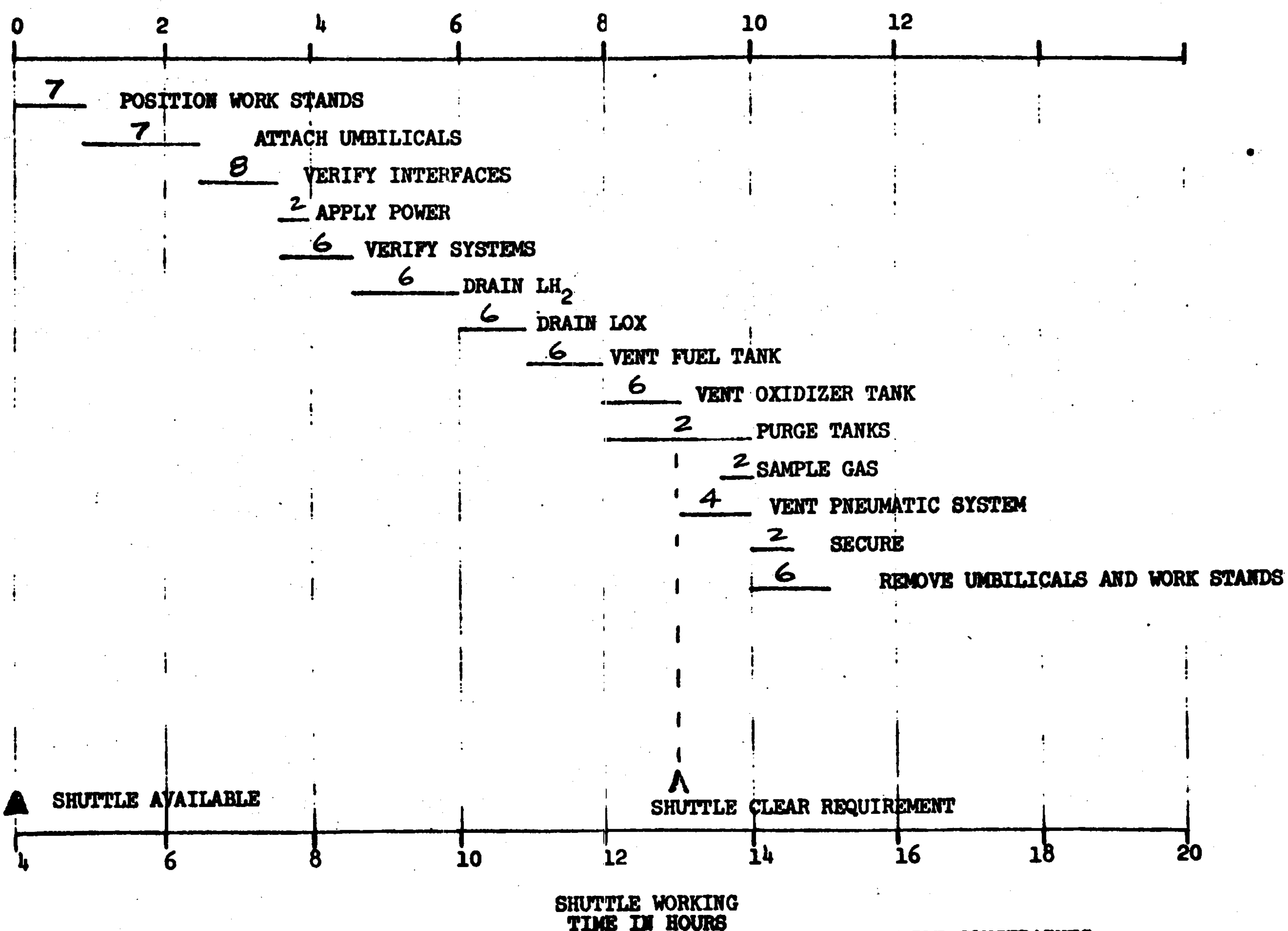
OPTION NUMBER	FUNCTION TITLE TUG GROUND SAFING AT SAFING AREA	FLOW BLOCK NO. 3.1.1



NOTE: NO RESIDUAL LIQUIDS

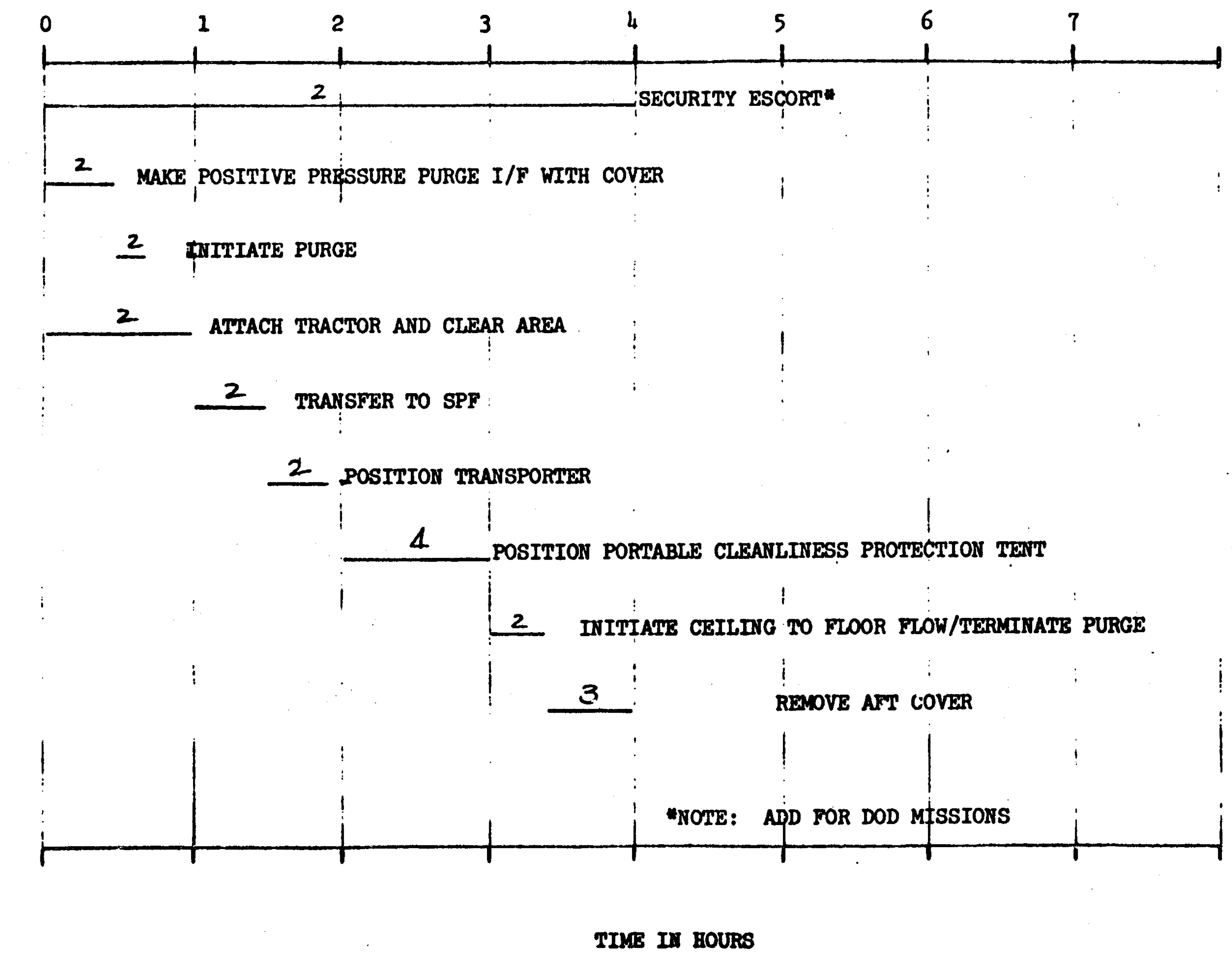
SHUTTLE CONSTRAINTS

OPTION NUMBER	FUNCTION TITLE TUG GROUND SAFING AT SAFING AREA	FLOW BLOCK NO. 3.1.1.a

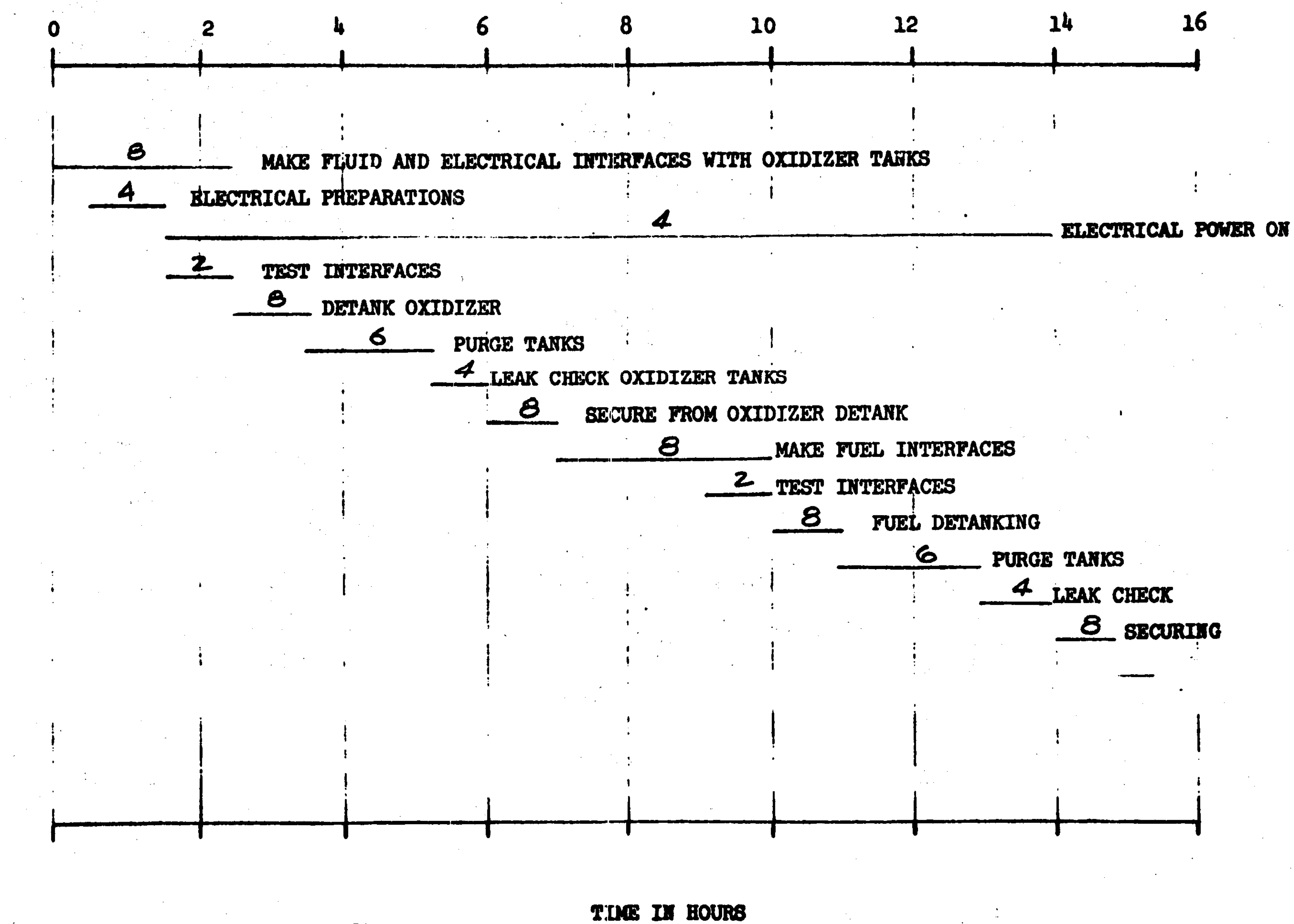


NOTE: RESIDUAL CRYO LIQUIDS FROM ABORT

OPTION NUMBER	FUNCTION TITLE TRANSFER TUG TO SPF	FLOW BLOCK NO. 3.1.2



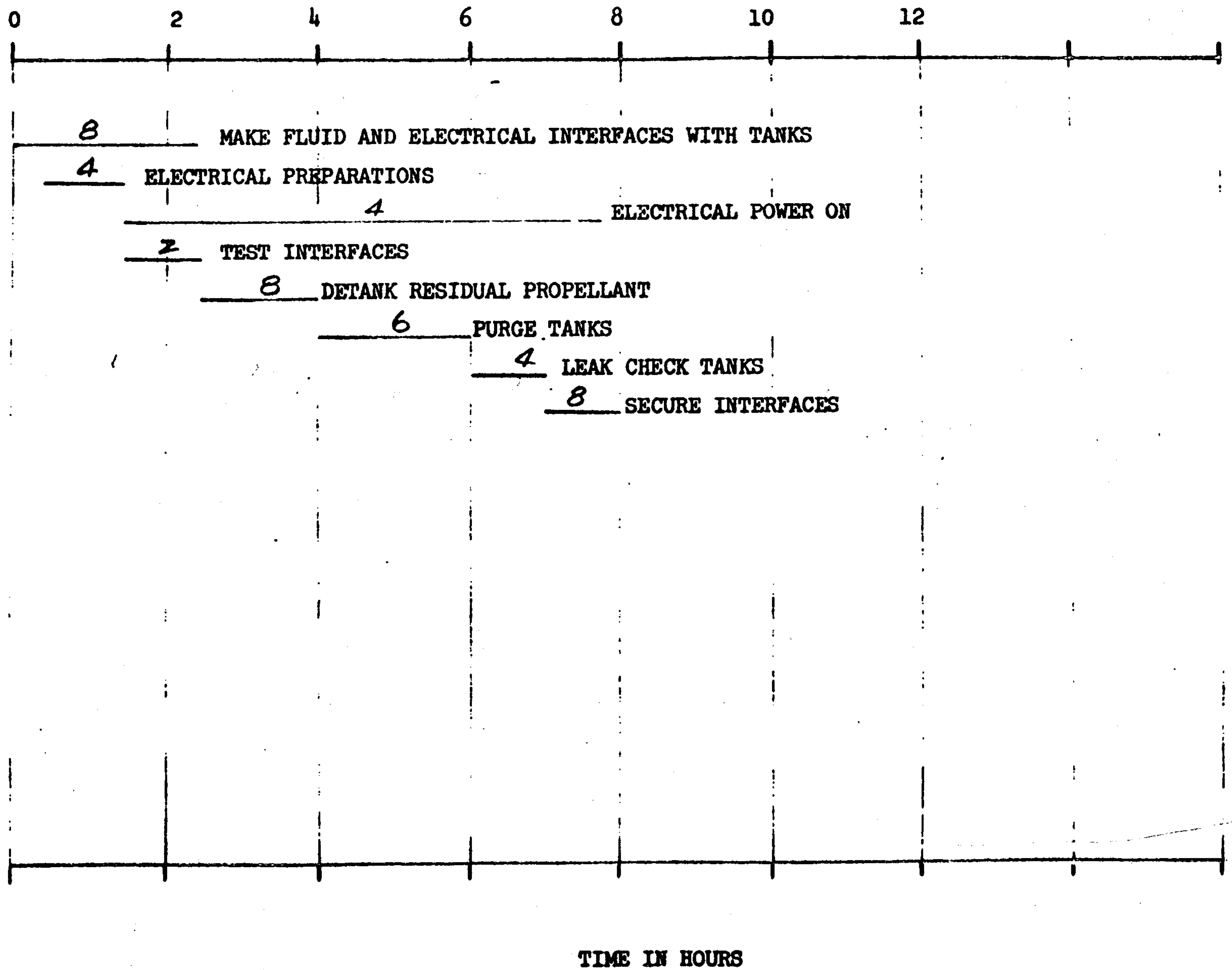
OPTION NUMBER	FUNCTION TITLE TUG ACPS SAFING REMOVABLE TANK SYSTEM	FLOW BLOCK NO. 3.1.3.a



NOTE: BIPROPELLANT TANK AT SPF

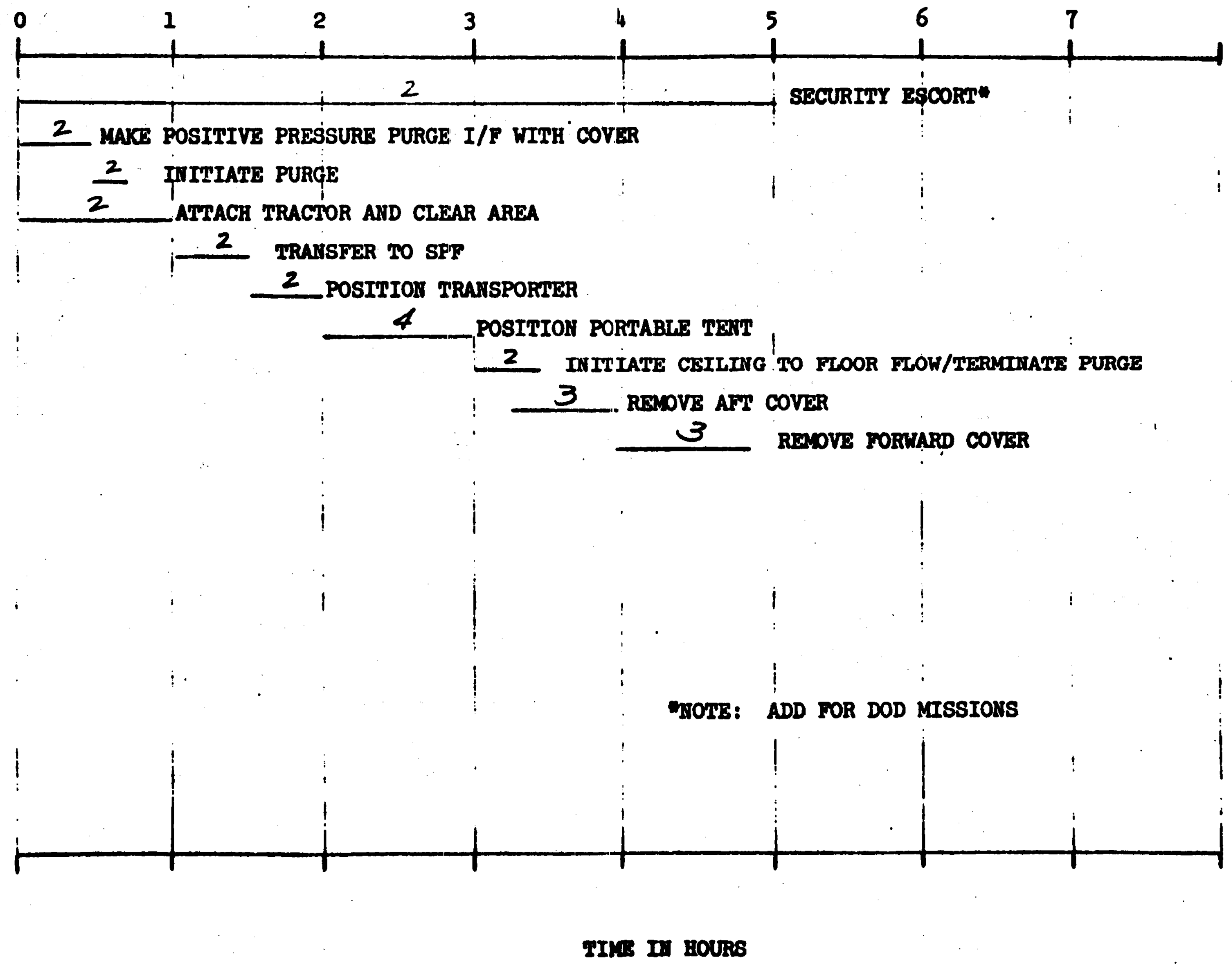
D-231

OPTION NUMBER	FUNCTION TITLE TUG ACPS SAFING REMOVABLE TANK SYSTEM	FLOW BLOCK NO. 3.1.3.b

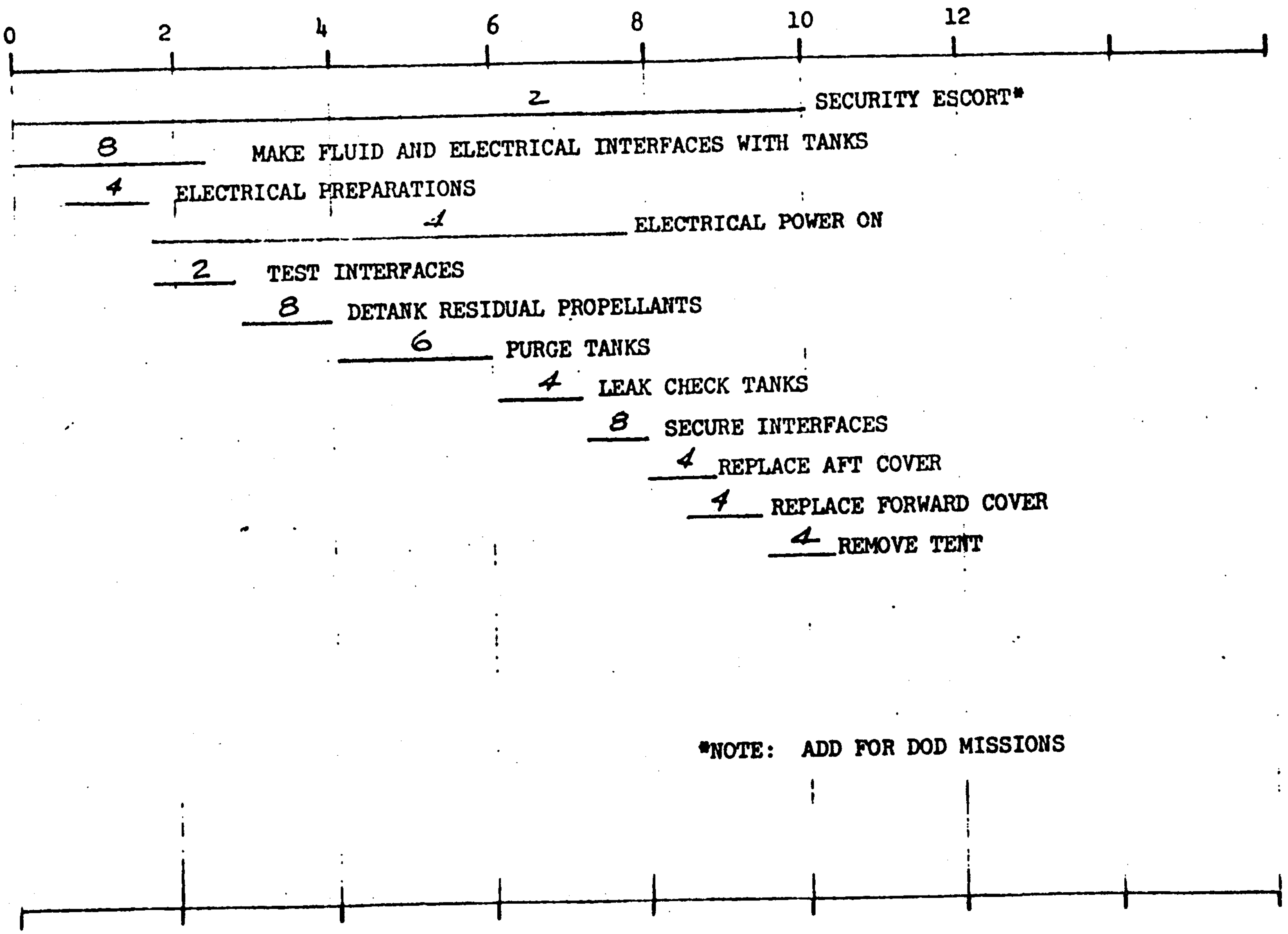


..TE: MONOPROPELLANT TANK AT SPF

OPTION NUMBER	FUNCTION TITLE TRANSFER TUG AND S/C TO SPF	FLOW BLOCK NO. 3.1.4



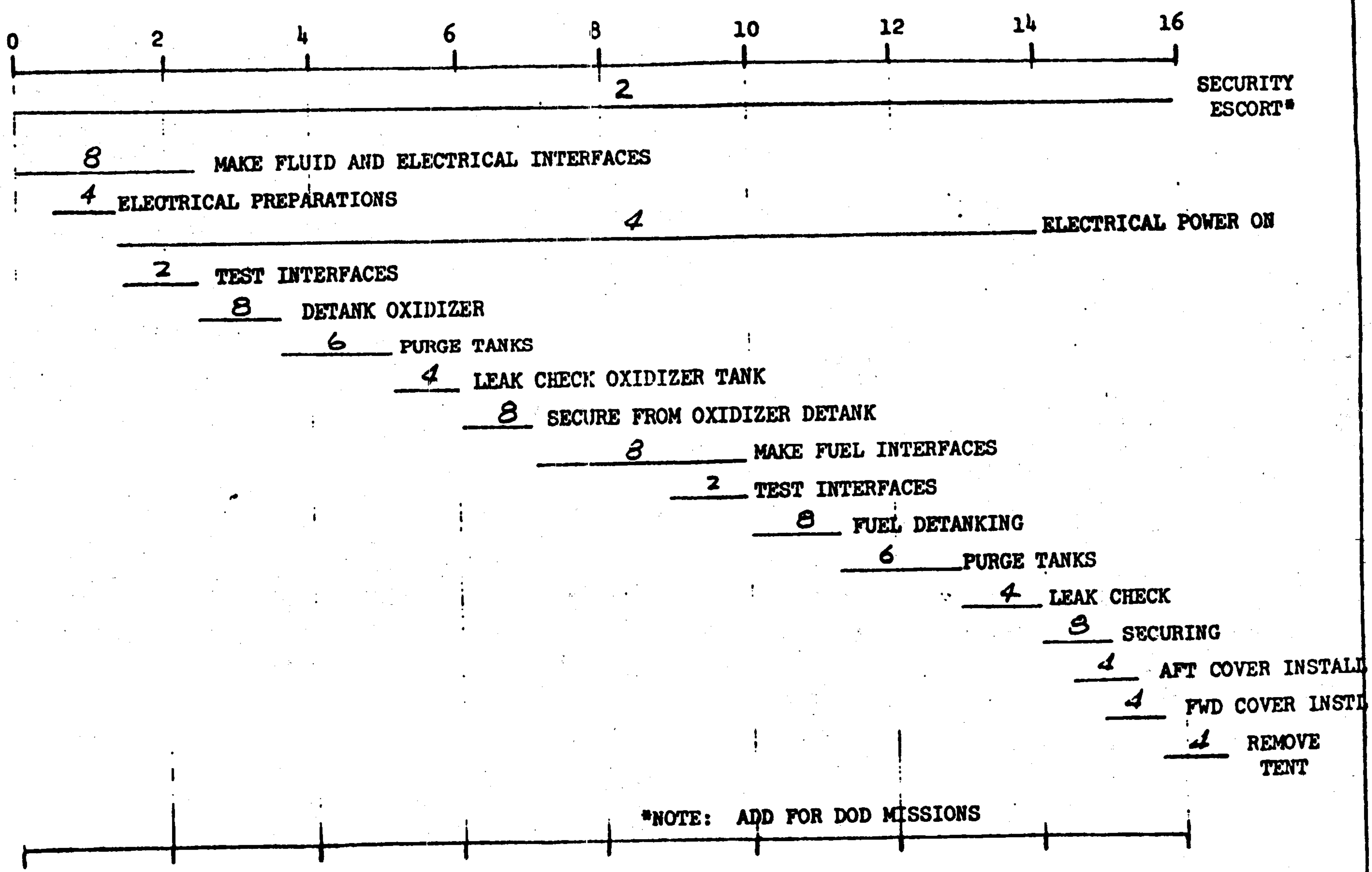
OPTION NUMBER	FUNCTION TITLE TUG SAFING	FLOW BLOCK NO. 3.1.6



TIME IN HOURS

NOTES: MONOPROPELLANT AT SPF

OPTION NUMBER	FUNCTION TITLE TUG SAFING	FLOW BLOCK NO. 3.1.7

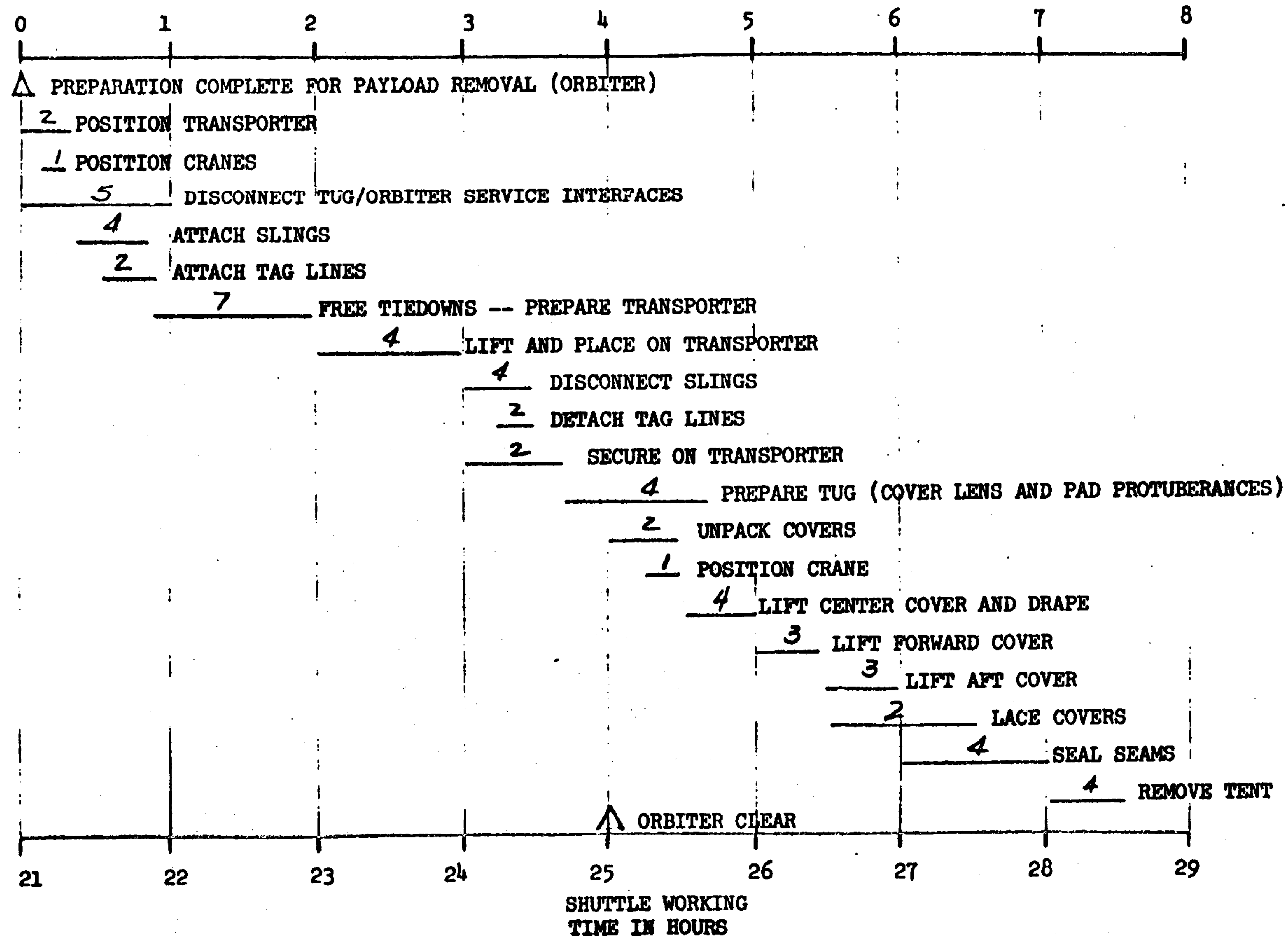


NOTES: BIPROPELLANT AT SPF

TIME IN HOURS

D-235

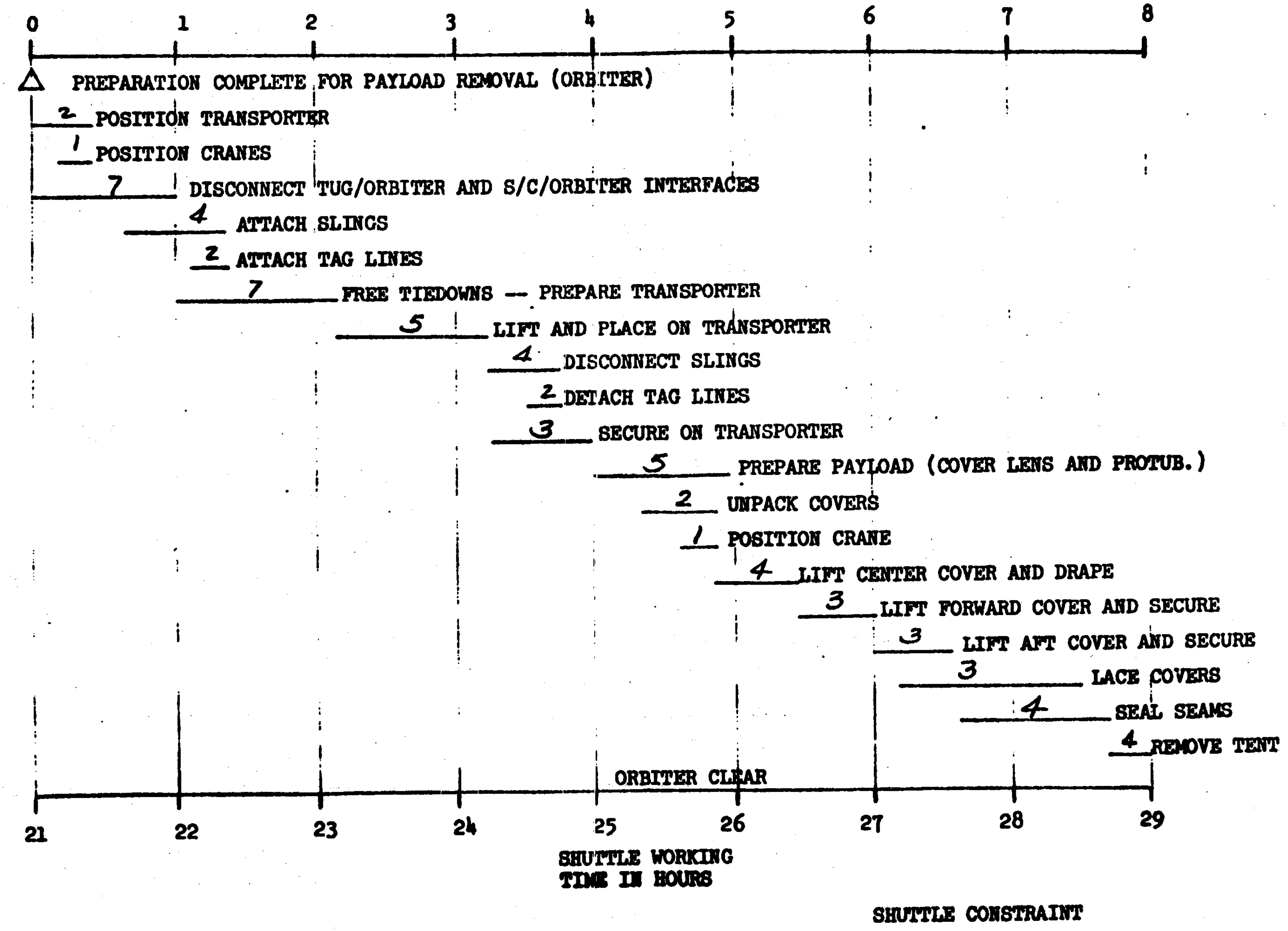
OPTION NUMBER	FUNCTION TITLE RECOVER TUG AT MCF	FLOW BLOCK NO. 3.2.3



NOTE: TWO CRANE OPERATORS PROVIDED BY SHUTTLE

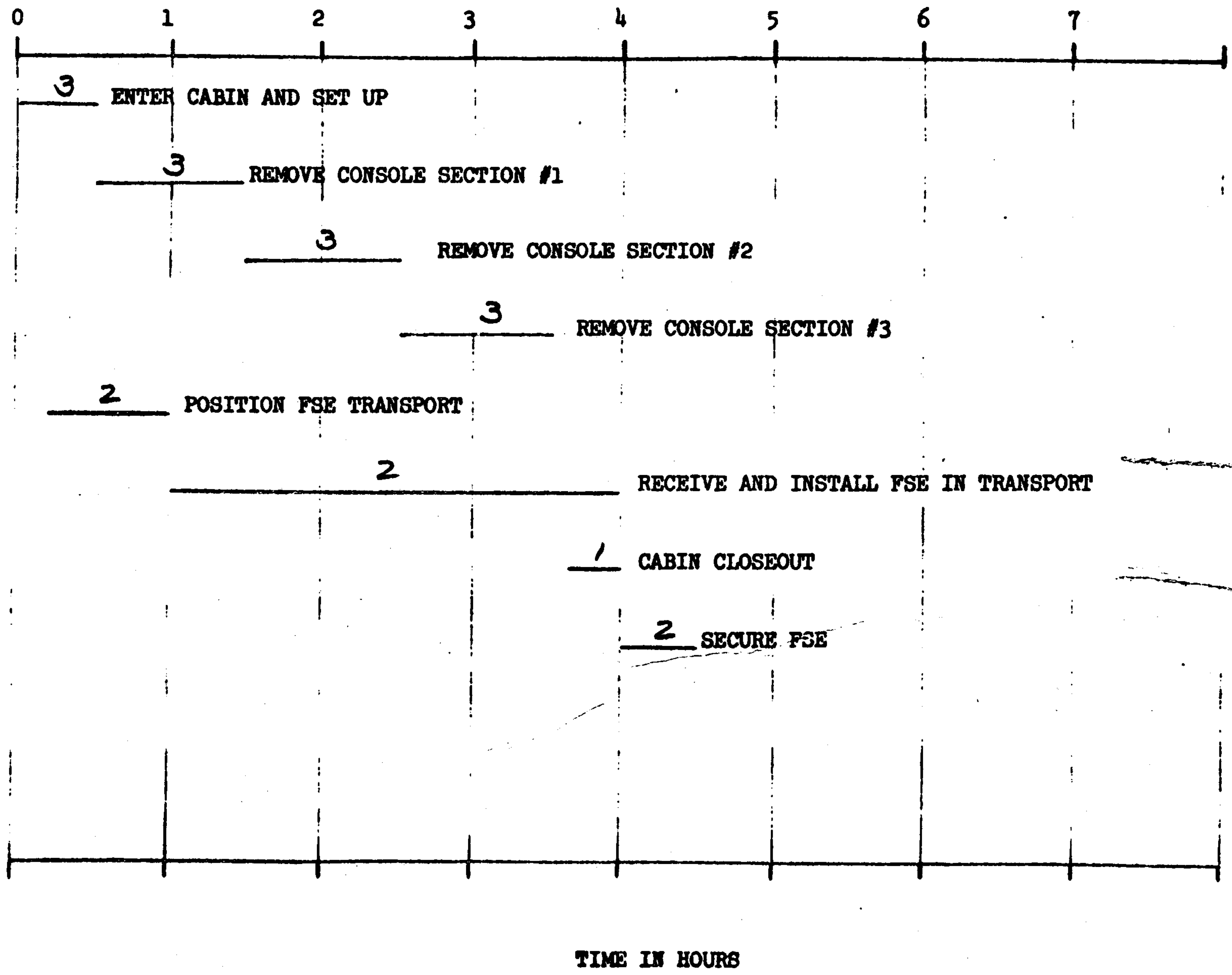
SHUTTLE CONSTRAINT

OPTION NUMBER	FUNCTION TITLE RECOVER TUG AND S/C AT MCF	FLOW BLOCK NO. 3.2.5

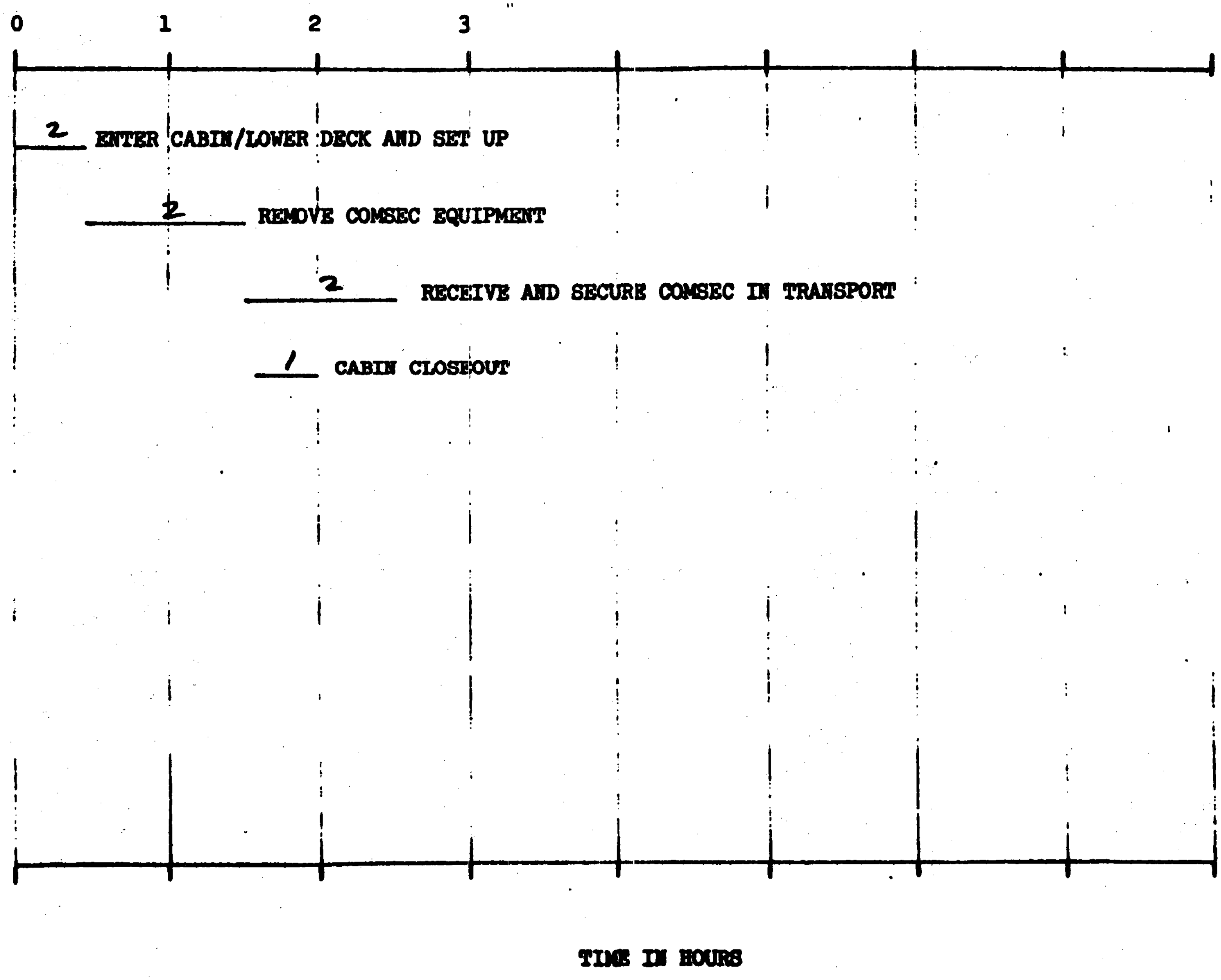


D-237

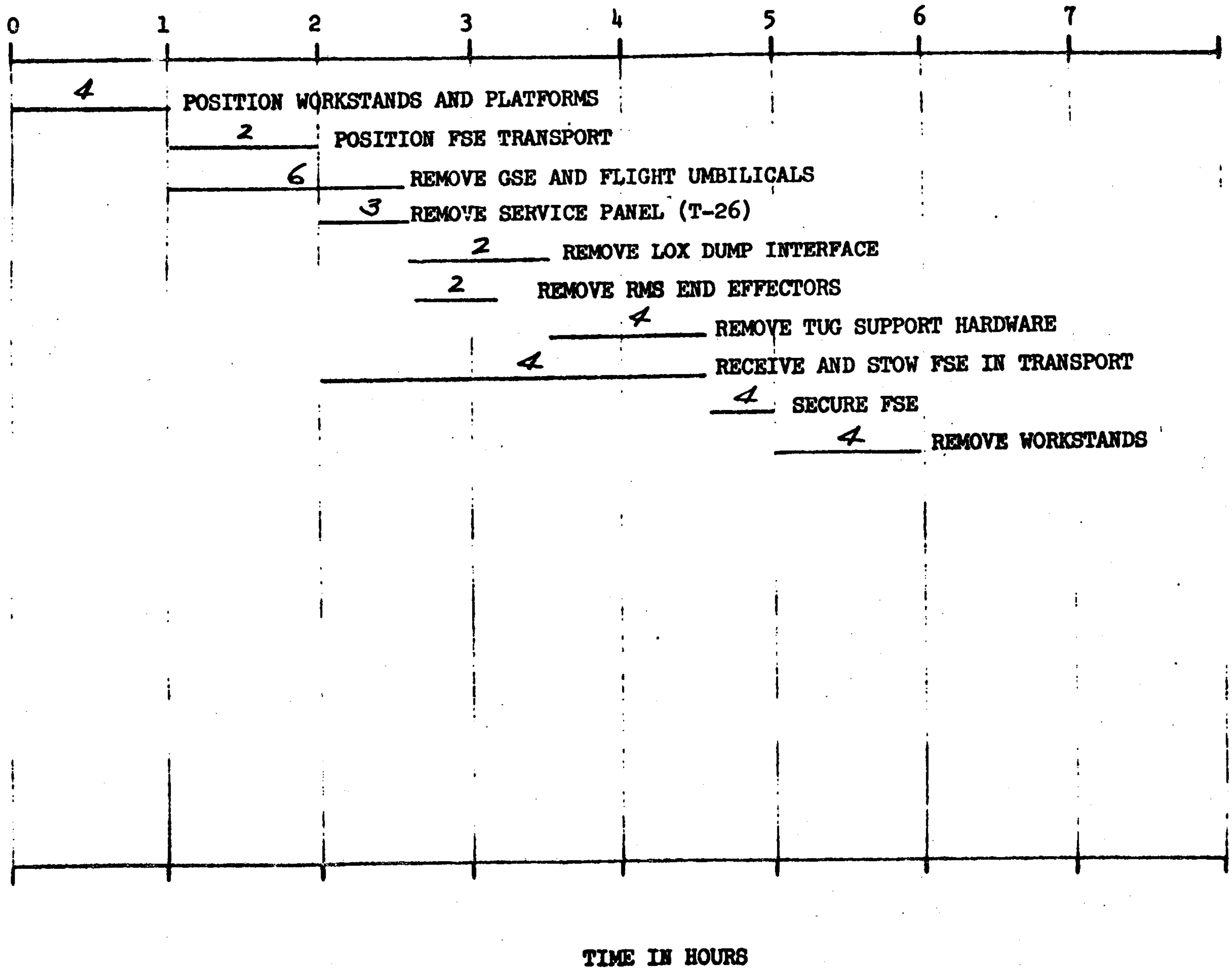
OPTION NUMBER	ALL	FUNCTION TITLE	RECOVER FSE (CABIN) EQUIPMENT (CONSOLE)	FLOW BLOCK NO.	3.2.6.a.



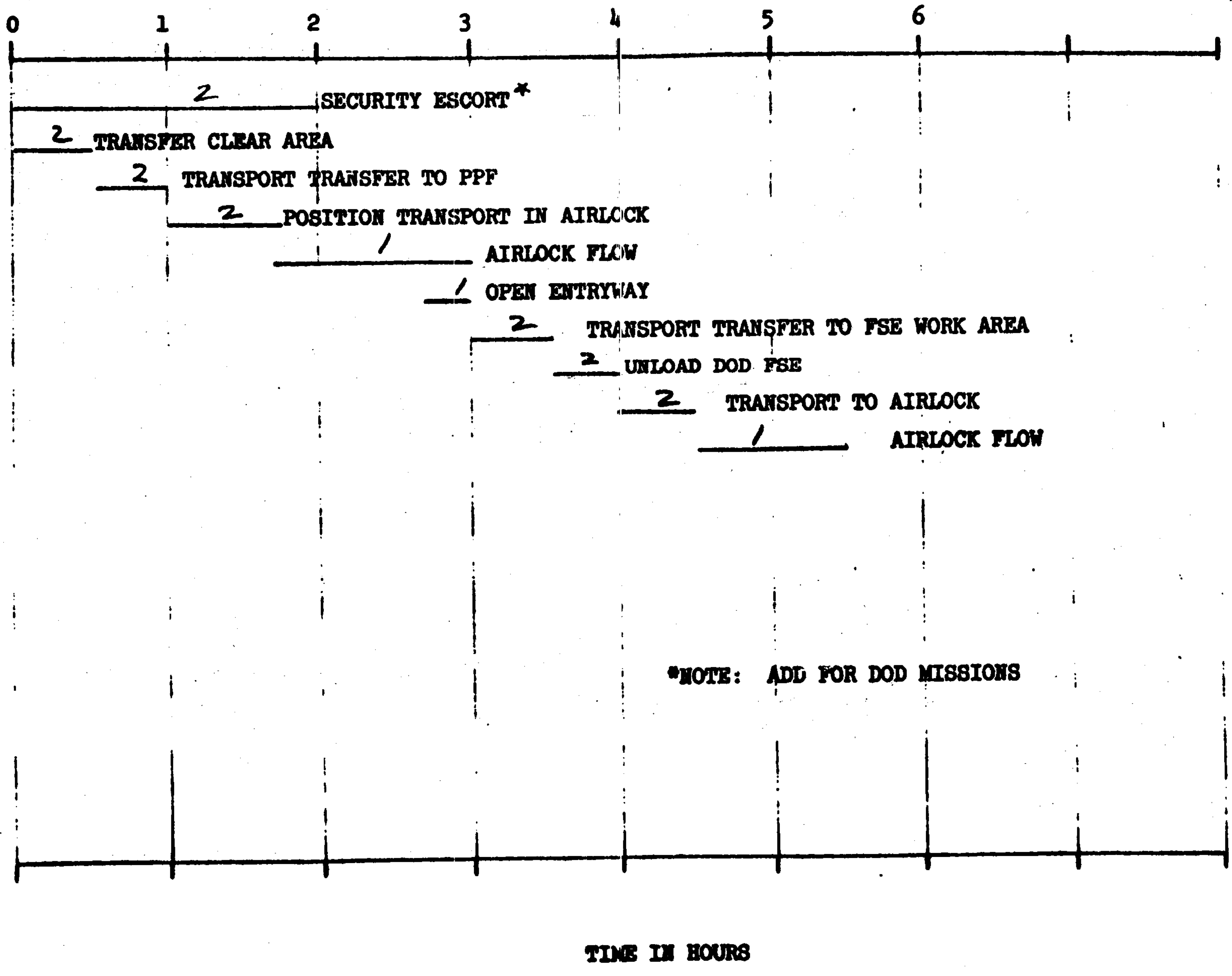
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
ALL DOD	RECOVER FSE (CABIN) EQUIPMENT (COMSEC)	3.2.6.b



OPTION NUMBER ALL	FUNCTION TITLE RECOVER FSE (PAYLOAD BAY) EQUIPMENT	FLOW BLOCK NO. 3.2.7

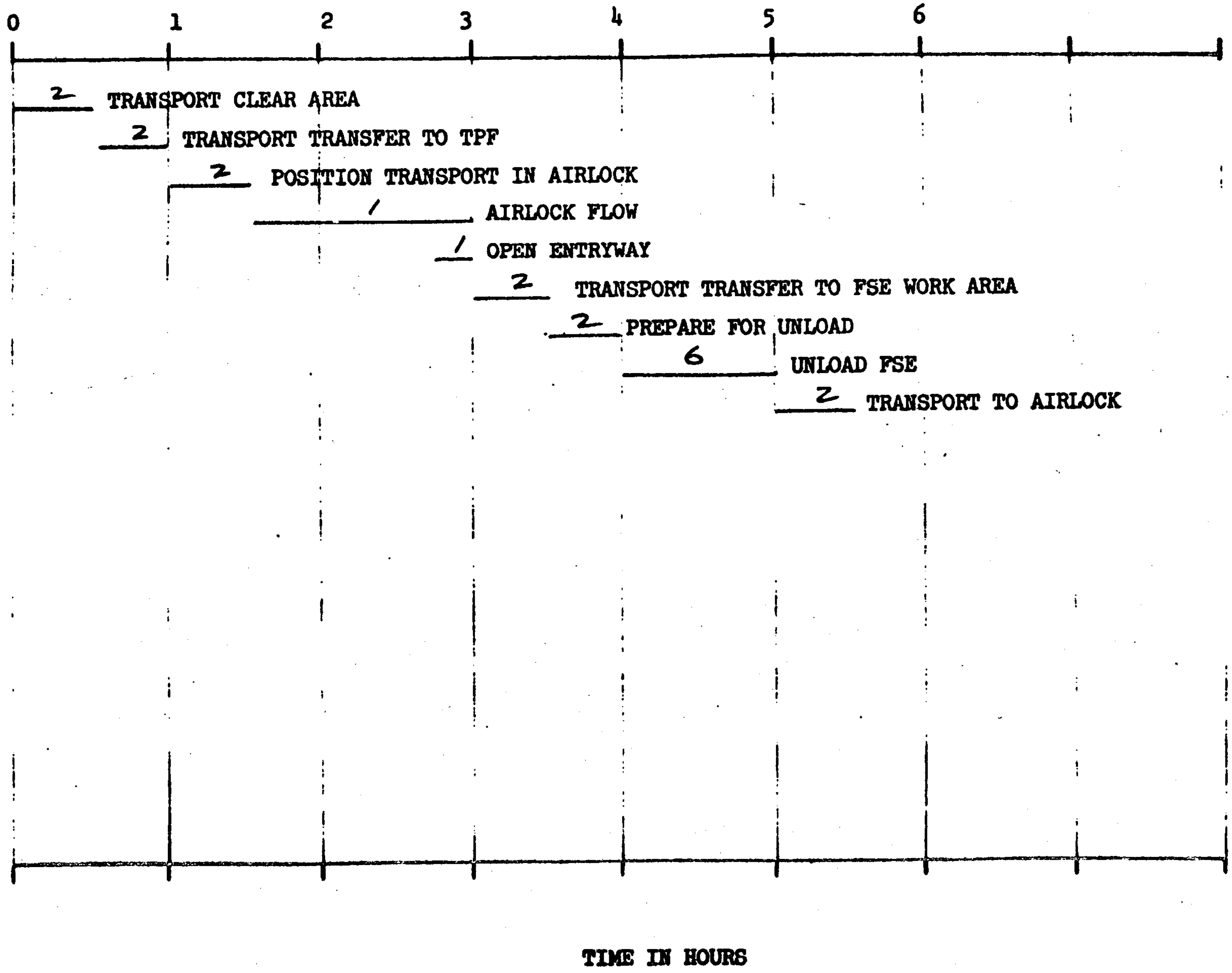


OPTION NUMBER	FUNCTION TITLE	TRANSFER FSE TO PPF	FLOW BLOCK NO.	3.2.8



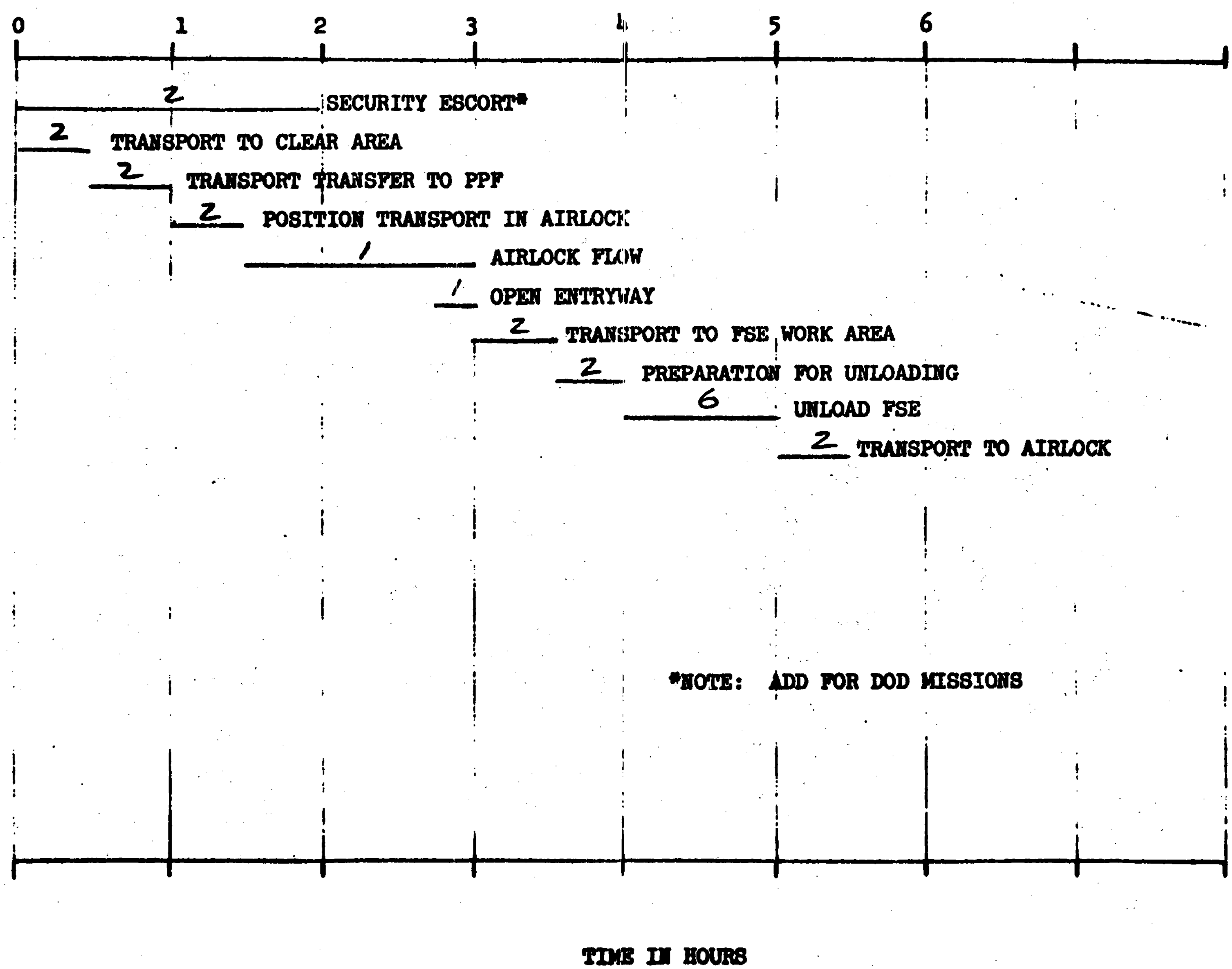
*NOTE: ADD FOR DOD MISSIONS

OPTION NUMBER	FUNCTION TITLE TRANSFER FSE TO TPF	FLOW BLOCK NO. 3.2.9



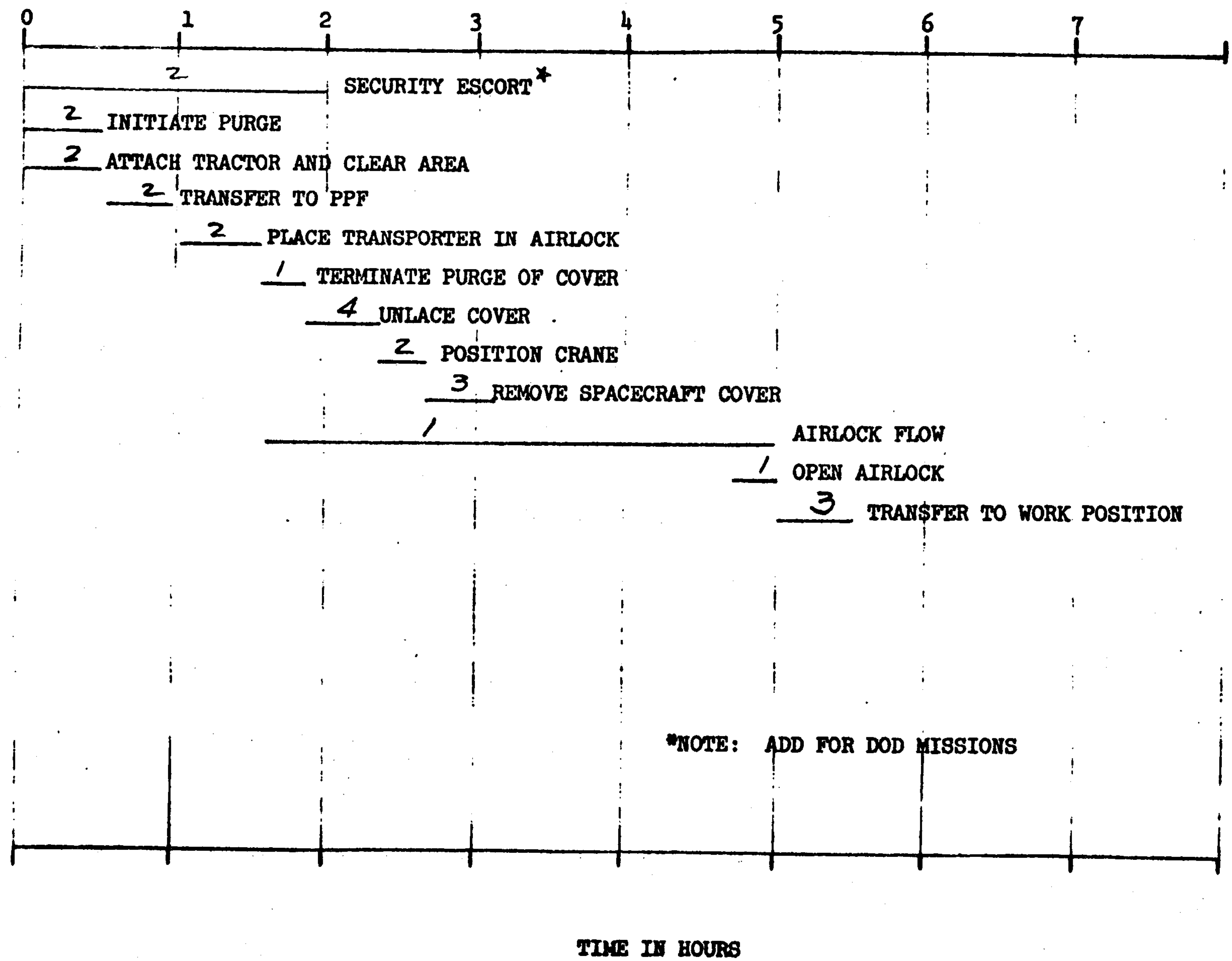
D-242

OPTION NUMBER	FUNCTION TITLE	TRANSFER FSE TO PPF	FLOW BLOCK NO.	3.2.10

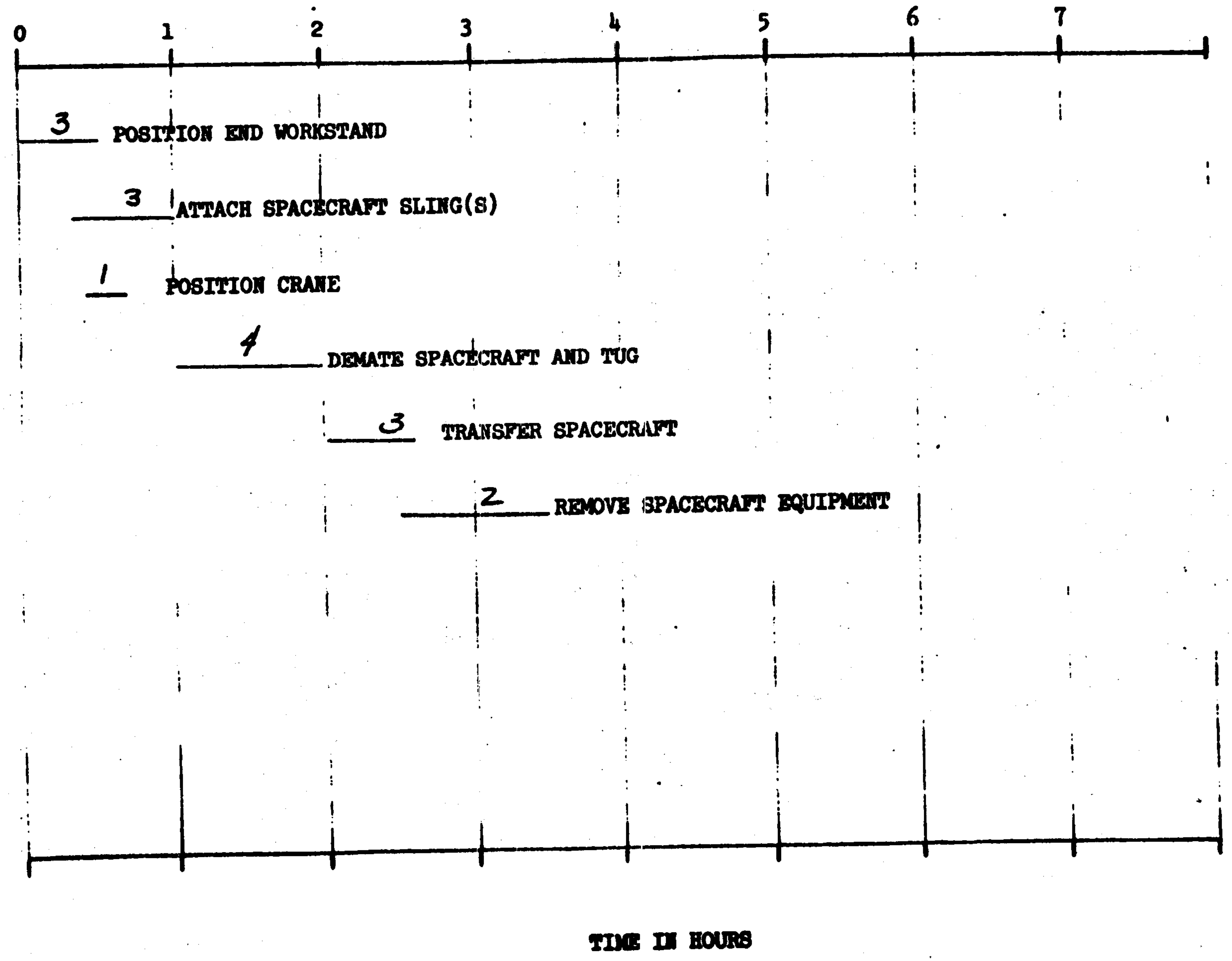


*NOTE: ADD FOR DOD MISSIONS

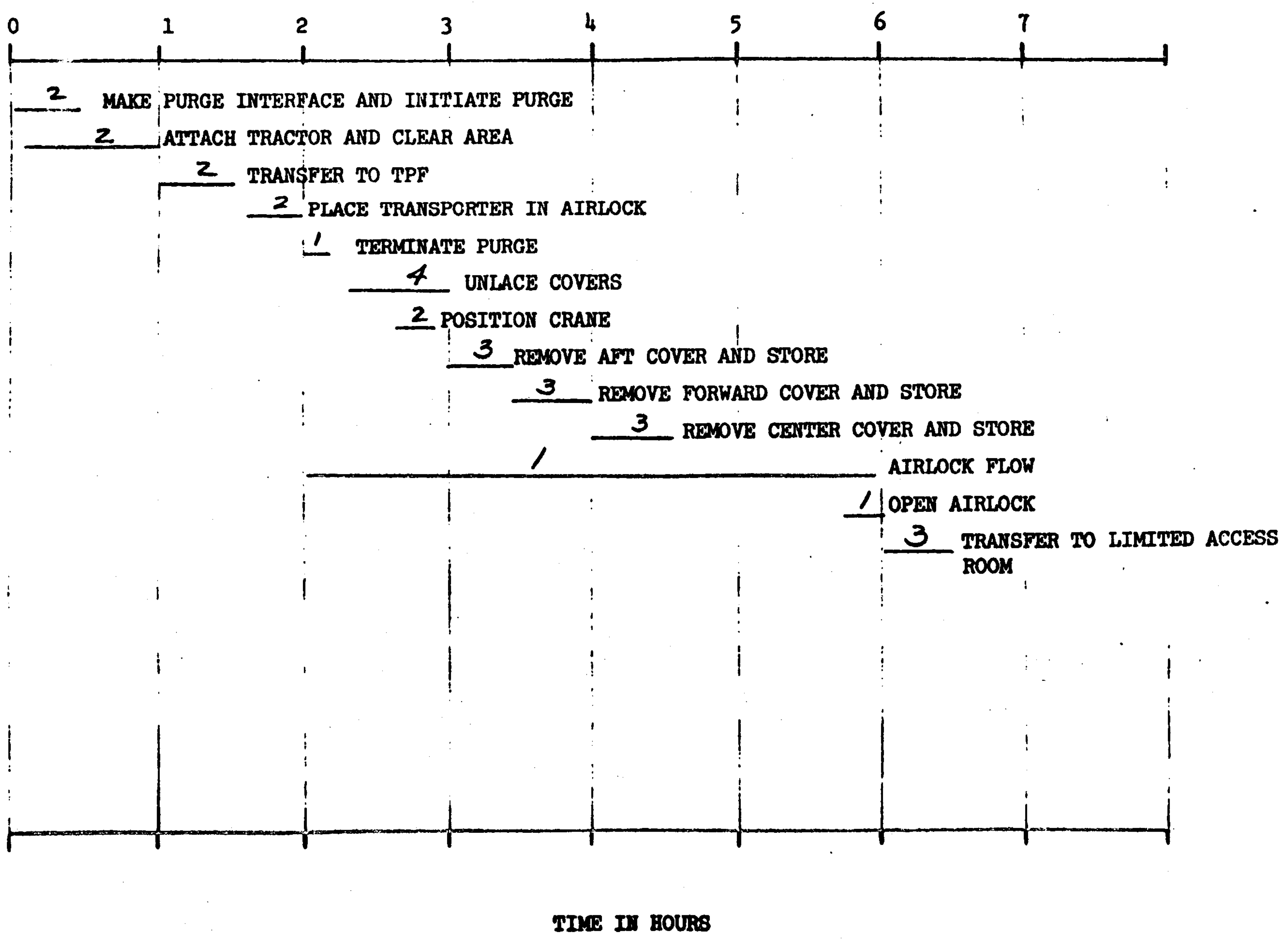
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
	TRANSFER TUG AND S/C TO PPF	3.3.1



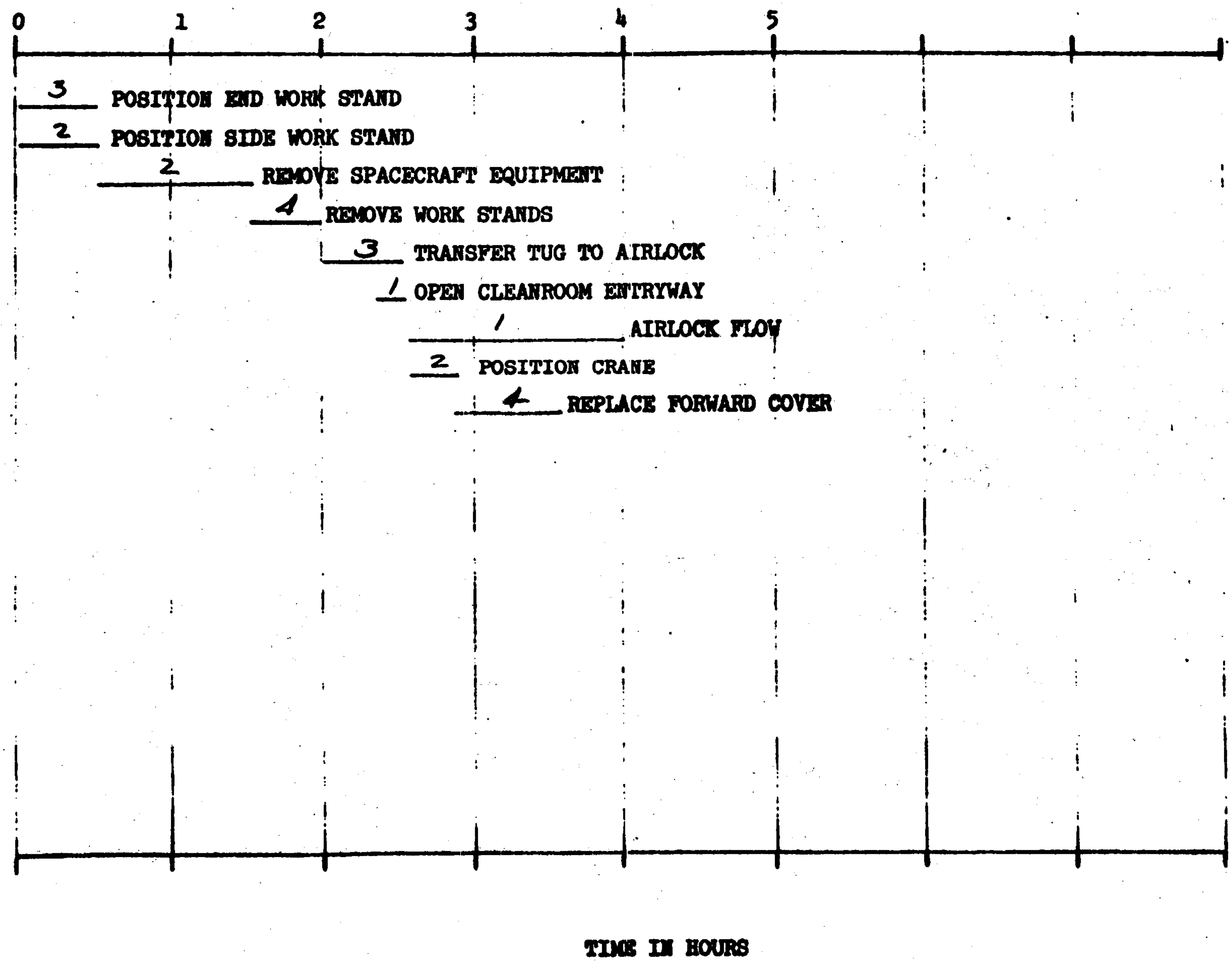
OPTION NUMBER	FUNCTION TITLE DEMATE TUG AND SPACECRAFT	FLOW BLOCK NO. 3.3.2



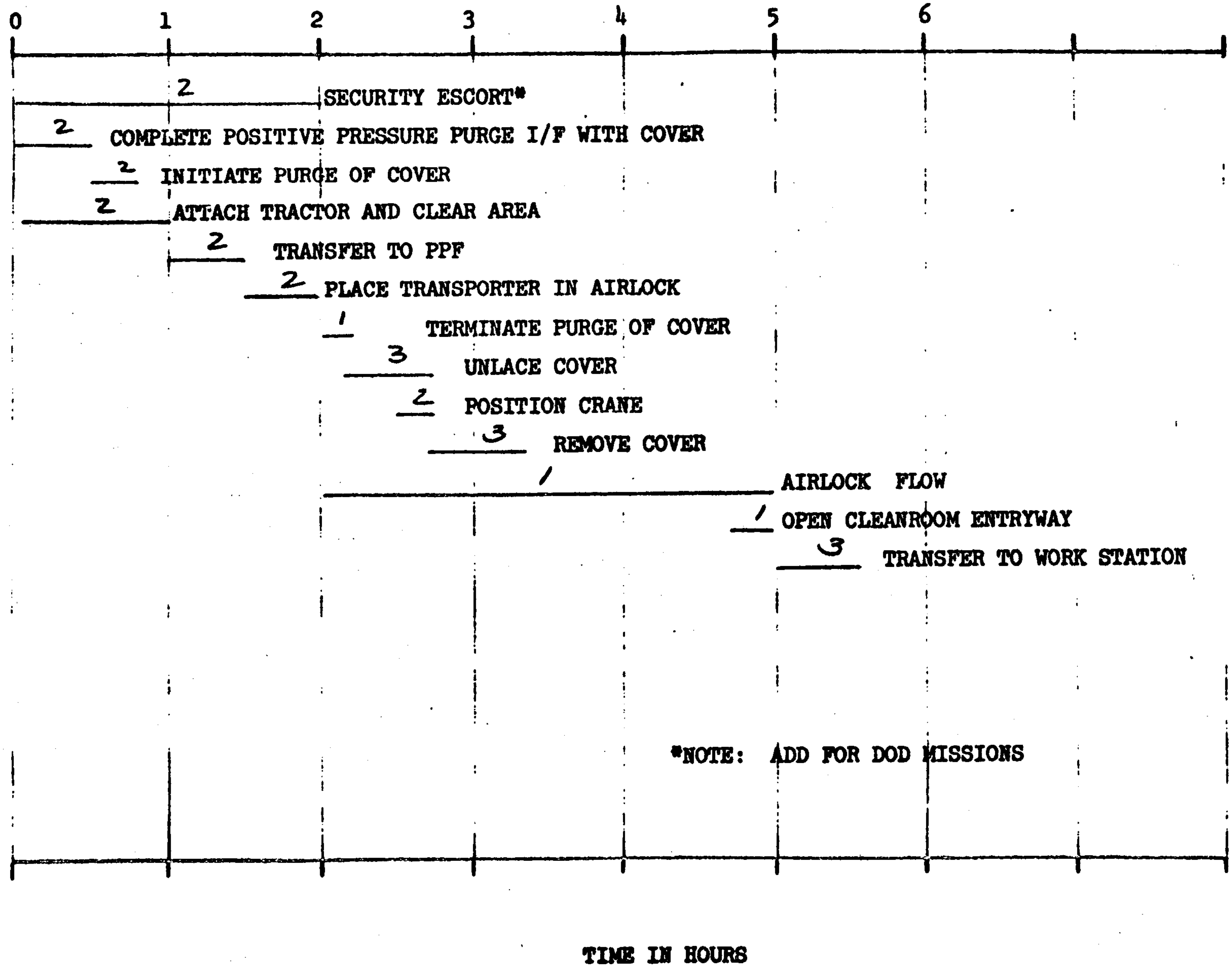
OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
	TRANSFER TUG TO TPF	3.3.3



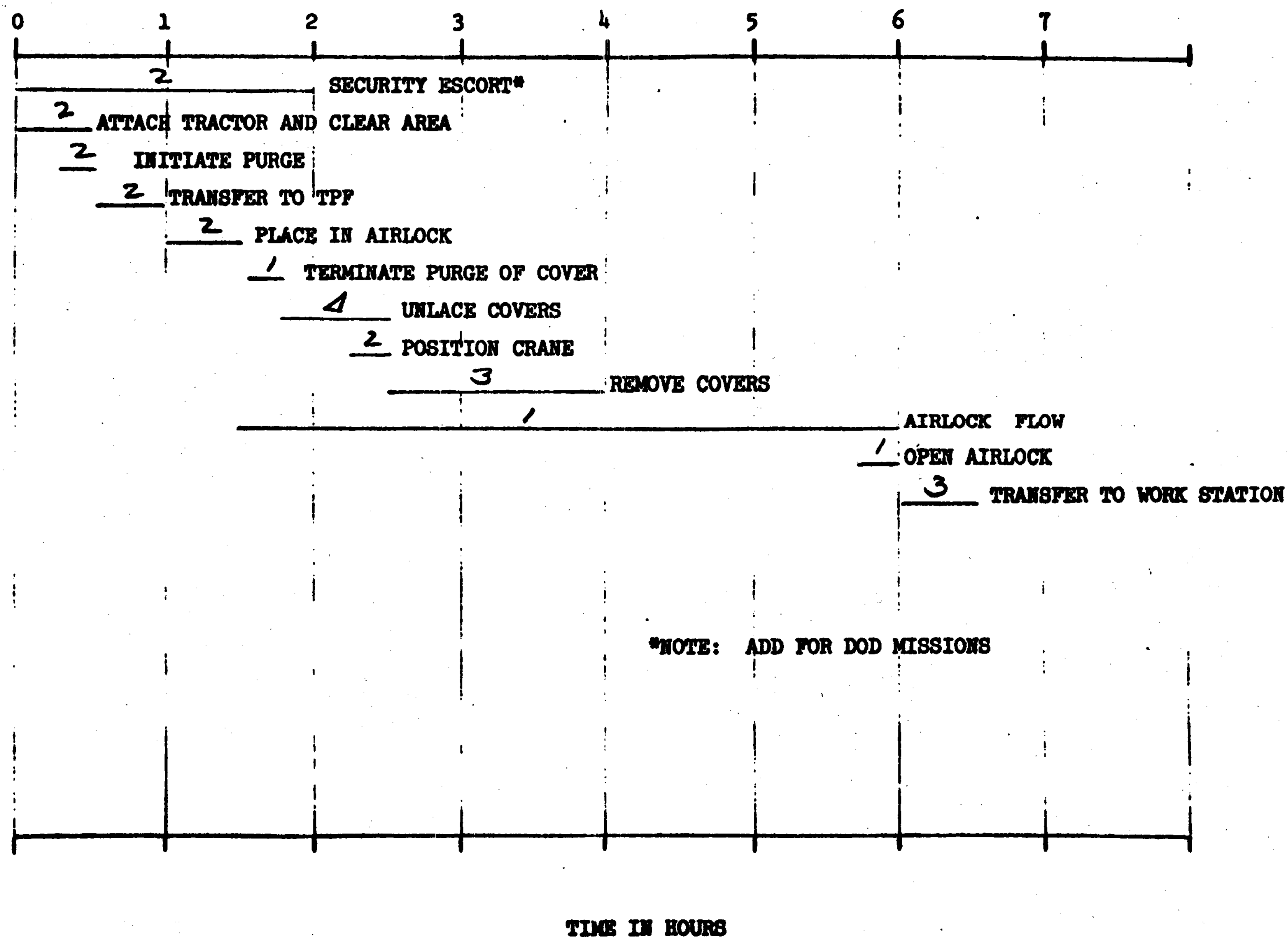
OPTION NUMBER	FUNCTION TITLE RECOVER SPACECRAFT EQUIPMENT	FLOW BLOCK NO. 3.3.4



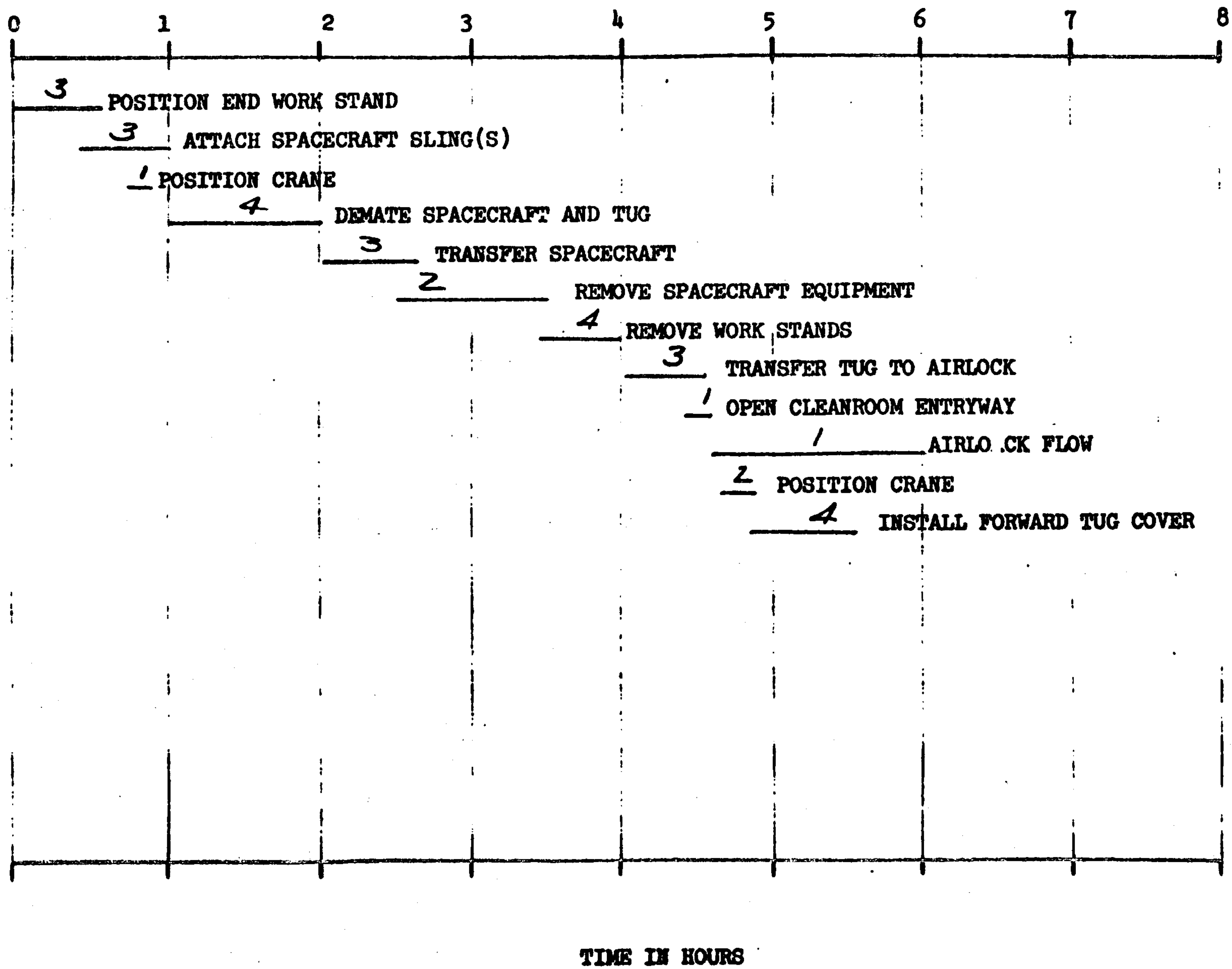
OPTION NUMBER	FUNCTION TITLE TRANSFER TUG TO PPF	FLOW BLOCK NO. 3.3.5



OPTION NUMBER	FUNCTION TITLE	TRANSFER TUG AND SPACECRAFT TO TPF	FLOW BLOCK NO.	3.3.6



OPTION NUMBER	FUNCTION TITLE	DEMATE TUG AND SPACECRAFT	FLOW BLOCK NO.	3.3.7



D-250

ION NUMBER	FUNCTION TITLE RECOVER SPACECRAFT EQUIPMENT	FLOW BLOCK NO. 3.3.8

0 1 2 3 4 5

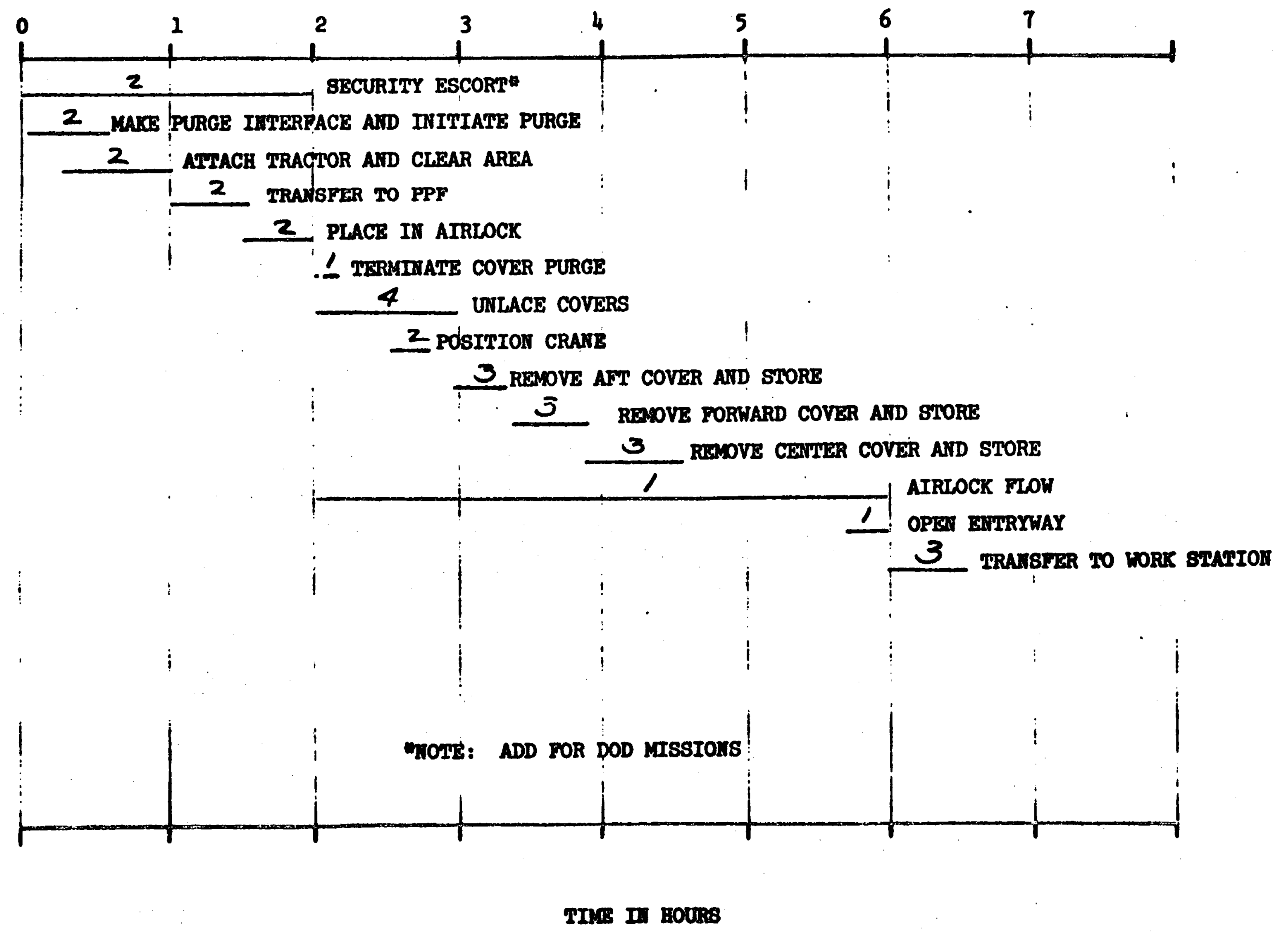
3 POSITION END WORK STAND

2 POSITION SIDE WORK STAND

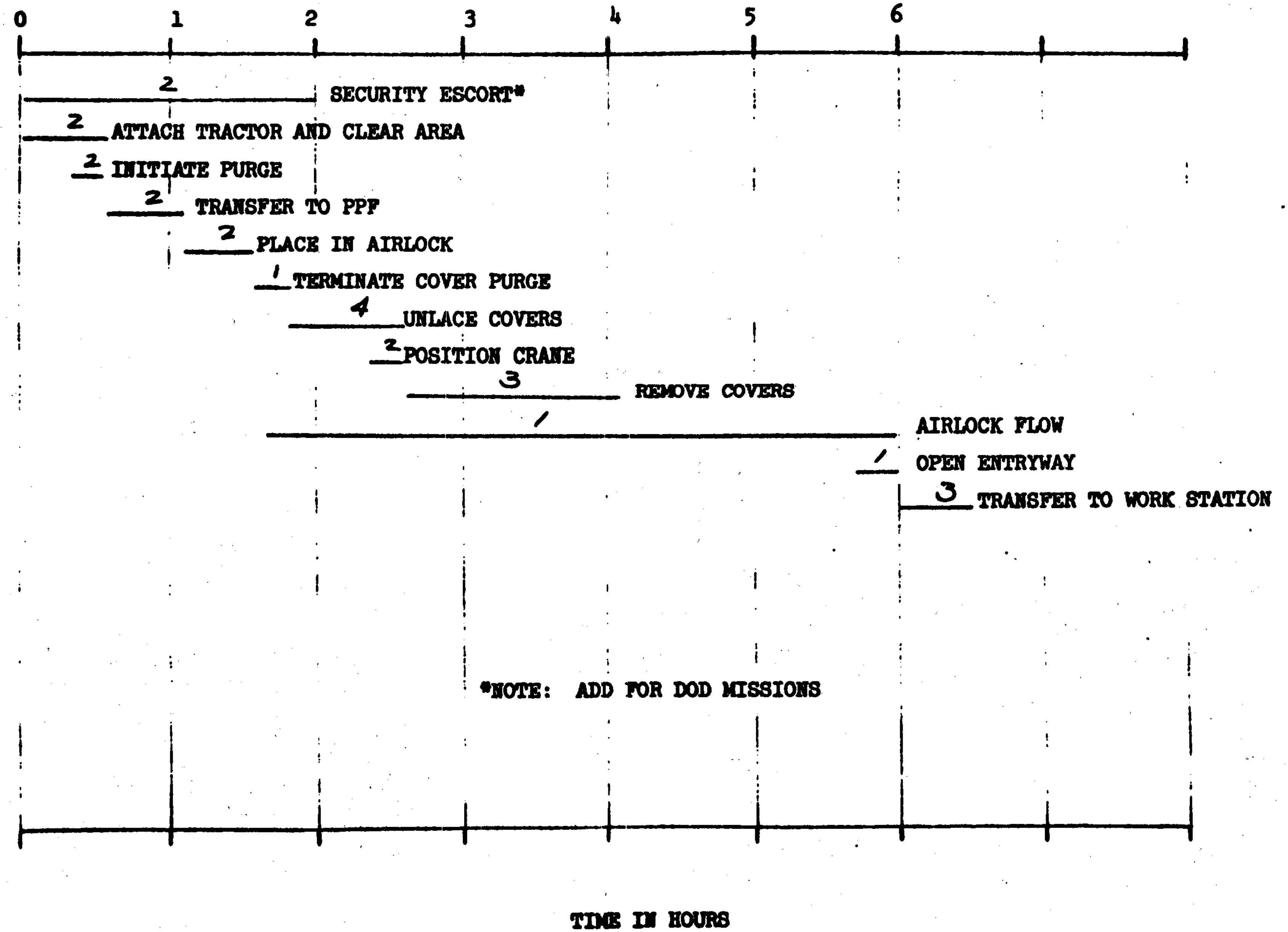
3 REMOVE SPACECRAFT EQUIPMENT*
(ADD TWO MEN FOR COMSEC AT WTR)*

TIME IN HOURS

OPTION NUMBER	FUNCTION TITLE	TRANSFER TUG TO PPF	FLOW BLOCK NO.	3.3.9



OPTION NUMBER	FUNCTION TITLE	TRANSFER TUG AND SPACECRAFT TO PPF	FLOW BLOCK NO.	3.3.10



0-253

ALTERNATE TIMELINES

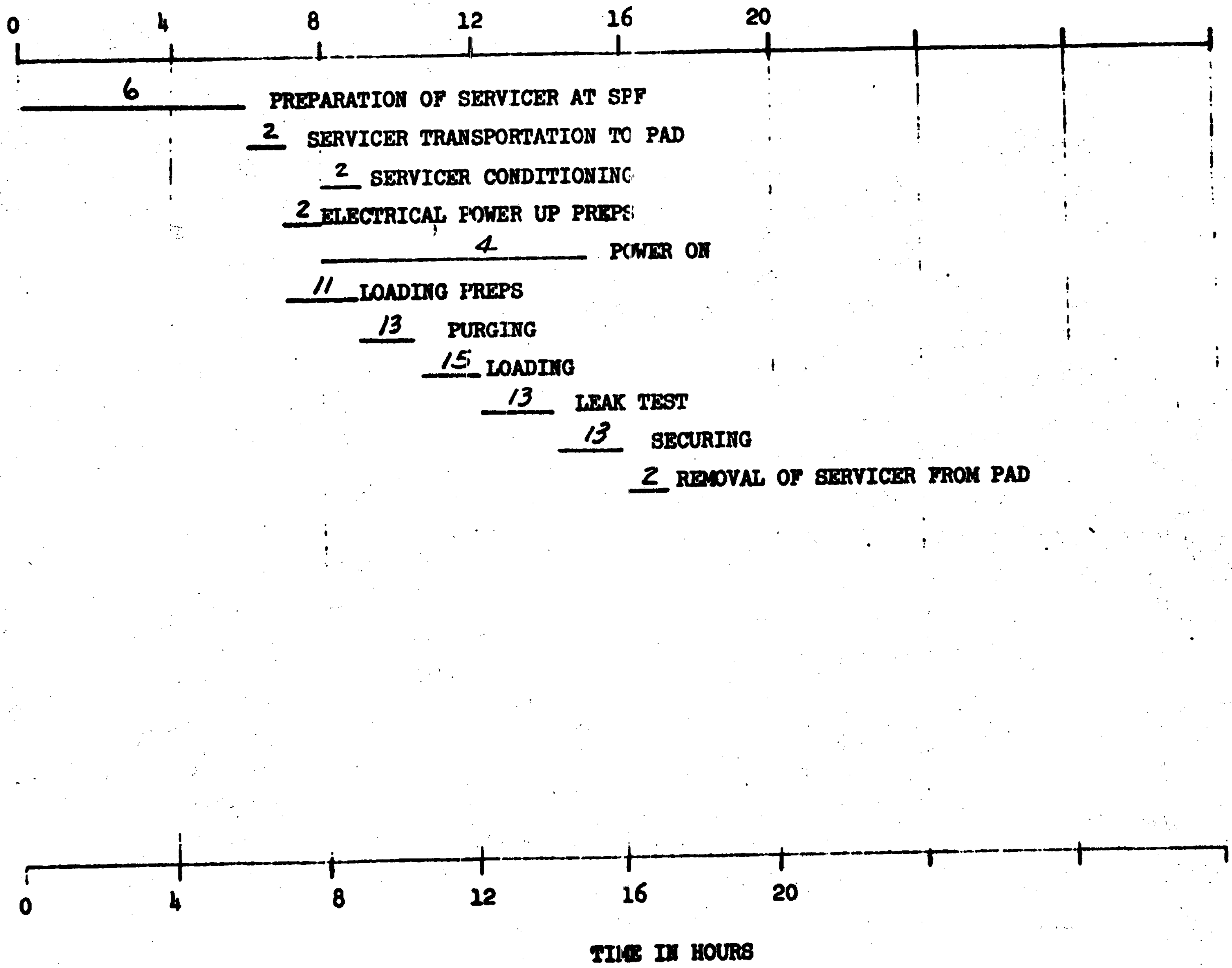
FOR THE

MDAC

CRYOGENIC TUG GROUND OPERATIONS

D-254

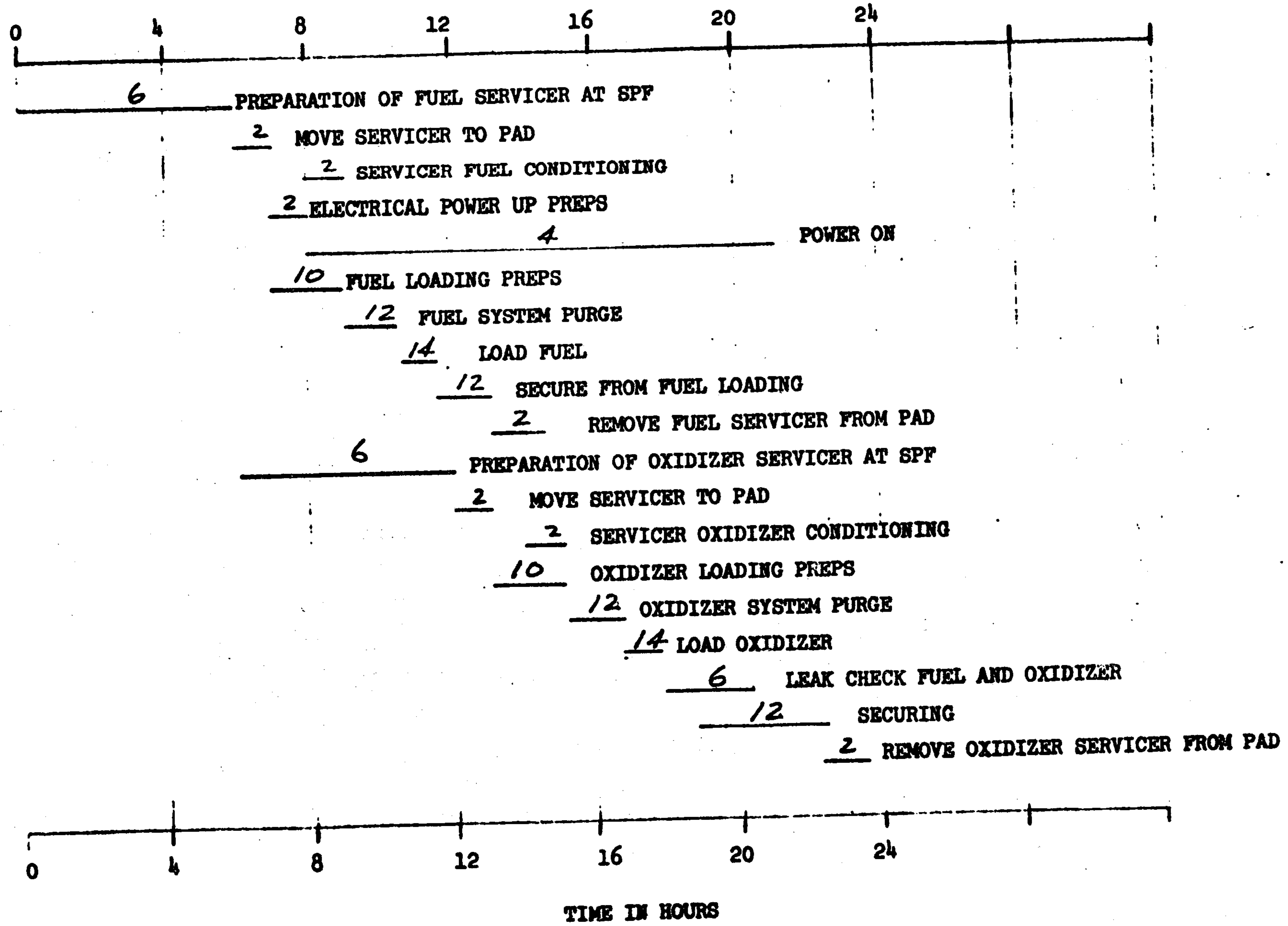
OPTION NUMBER	FUNCTION TITLE STORABLE PROPELLANT SERVICING*	FLOW BLOCK NO. 2.1.6.a (ALTERNATE)



*MONOPROPELLANT AT LAUNCH PAD

D-255

OPTION NUMBER	FUNCTION TITLE STORABLE PROPELLANT SERVICING*	FLOW BLOCK NO. 2.1.6.b (ALTERNATE)



*BIPROPELLANT AT LAUNCH PAD

OPTION NUMBER	FUNCTION TITLE	TUG ACPS SAFING	FLOW BLOCK NO.	3.1.3.a (ALTERNATE)

TIME IN HOURS

0 4 8 12 16 20 24

2 TRANSPORT SERVICER TO AREA

3 POSITION SERVICER AND PREPARE SERVICER

8 MAKE FLUID AND ELECTRICAL INTERFACES WITH OXIDIZER TANKS

4 ELECTRICAL PREPARATION

4 ELECTRICAL POWER ON

2 TEST INTERFACES

8 DETANK OXIDIZER

6 PURGE TANKS

4 LEAK CHECK OXIDIZER DETANK

8 SECURE OXIDIZER DETANK

8 MAKE FLUID AND ELECTRICAL INTERFACES WITH FUEL TANKS

2 TEST INTERFACES

8 FUEL DETANKING

6 PURGE TANKS

4 LEAK CHECK

8 SECURE

3 TRANSPORT SERVICER TO SPF

4 SET UP CLEANLINESS TENT

0 OPEN PAYLOAD BAY DOORS

4 SET UP WORK PLATFORMS

▲ SHUTTLE CLEAR REQUIREMENT ▲ SHUTTLE CLEAR

7 11 15 19 23 27

SHUTTLE TIME IN HOURS

NOTE: BIPROPELLANT AT SAFING AREA

OPTION NUMBER	FUNCTION TITLE	FLOW BLOCK NO.
	TUG ACPS SAFING	3.1.3.b(ALTERNATE)

TIME IN HOURS

0 2 4 6 8 10 12 14

3 TRANSPORT SERVICER TO AREA

3 POSITION SERVICER AND PREPARE SERVICER

8 MAKE FLUID AND ELECTRICAL INTERFACES

4 ELECTRICAL PREPARATIONS

4 ELECTRICAL POWER ON

2 TEST INTERFACES

8 DETANK RESIDUAL PROPELLANT

6 PURGE TANKS

4 LEAK CHECK TANKS

8 SECURE INTERFACES

3 TRANSPORT SERVICER TO SPF

4 SET UP CLEANLINESS TENT

0 OPEN PAYLOAD BAY DOORS

4 SET UP WORK PLATFORMS

SHUTTLE CLEAR RQMT

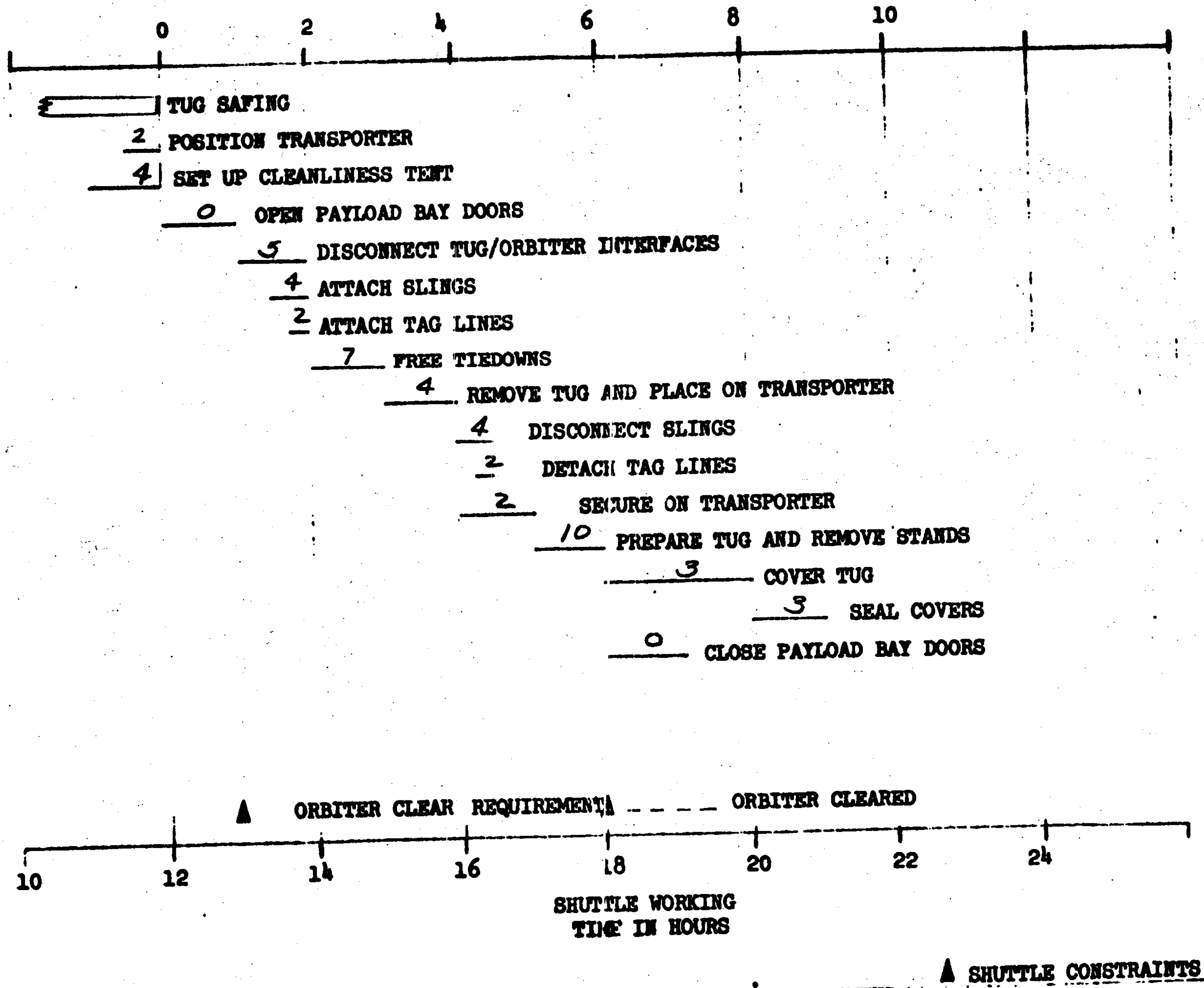
SHUTTLE CLEAR

7 9 11 13 15 17

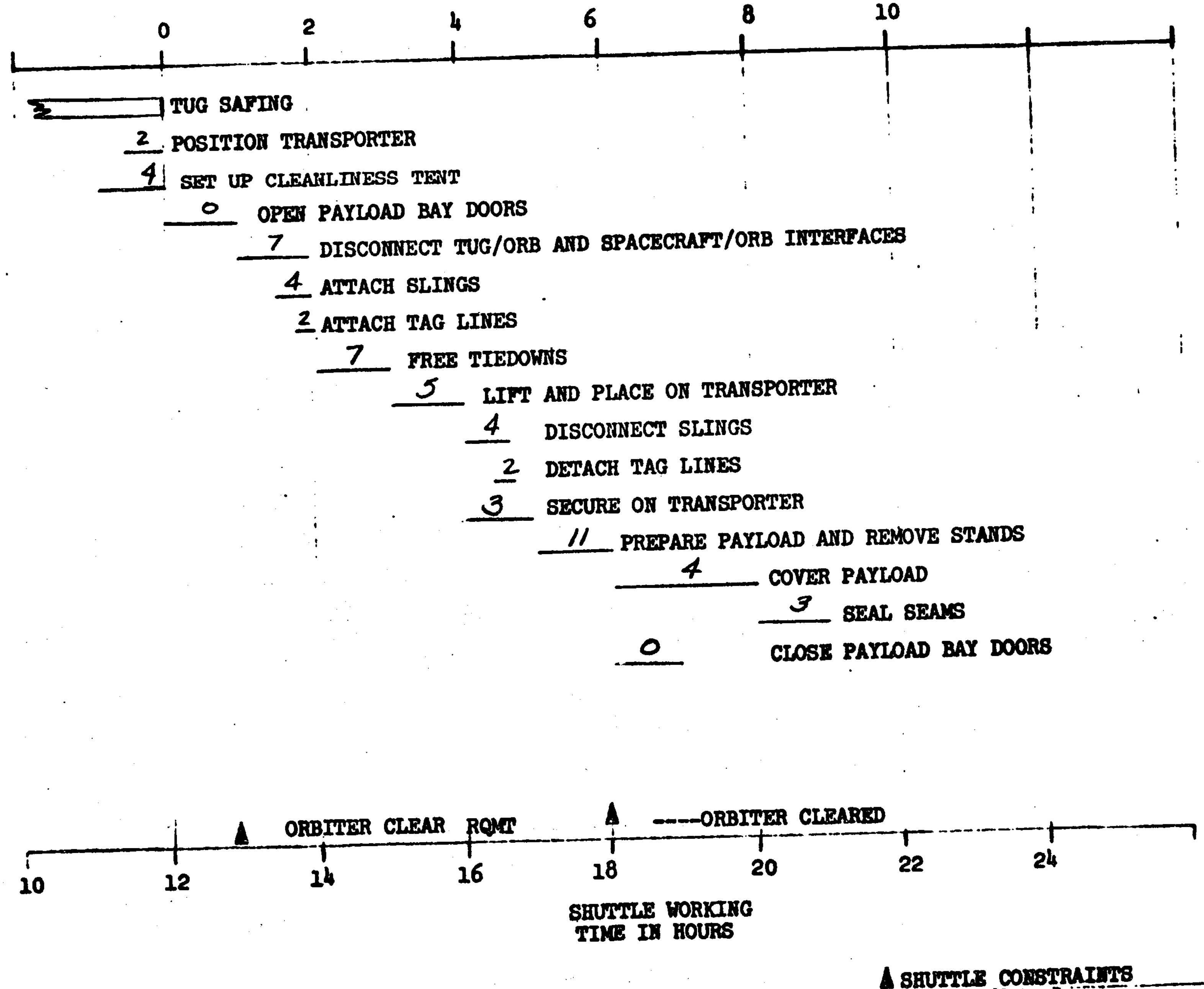
SHUTTLE TIME IN HOURS

NOTE: MONOPROPELLANT AT SAFING AREA

OPTION NUMBER	FUNCTION TITLE RECOVER TUG AT SAFING AREA	FLOW BLOCK NO. 3.2.2



OPTION NUMBER	FUNCTION TITLE RECOVER TUG AND S/C AT SAFING AREA	FLOW BLOCK NO. 3.2.4



D-260

11.10 Appendix E GSE Description Sheets

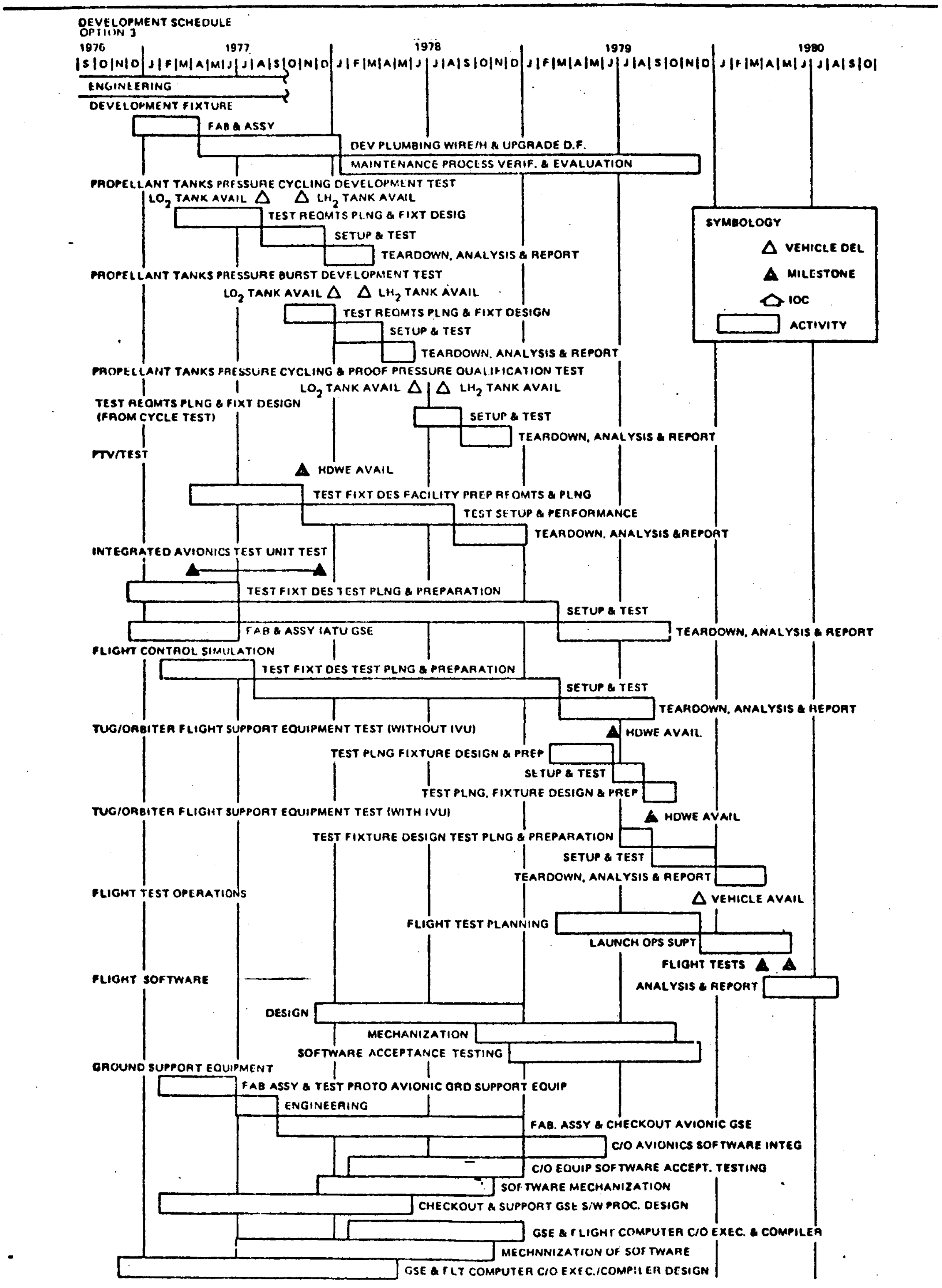
TABLE OF CONTENTS

E-2

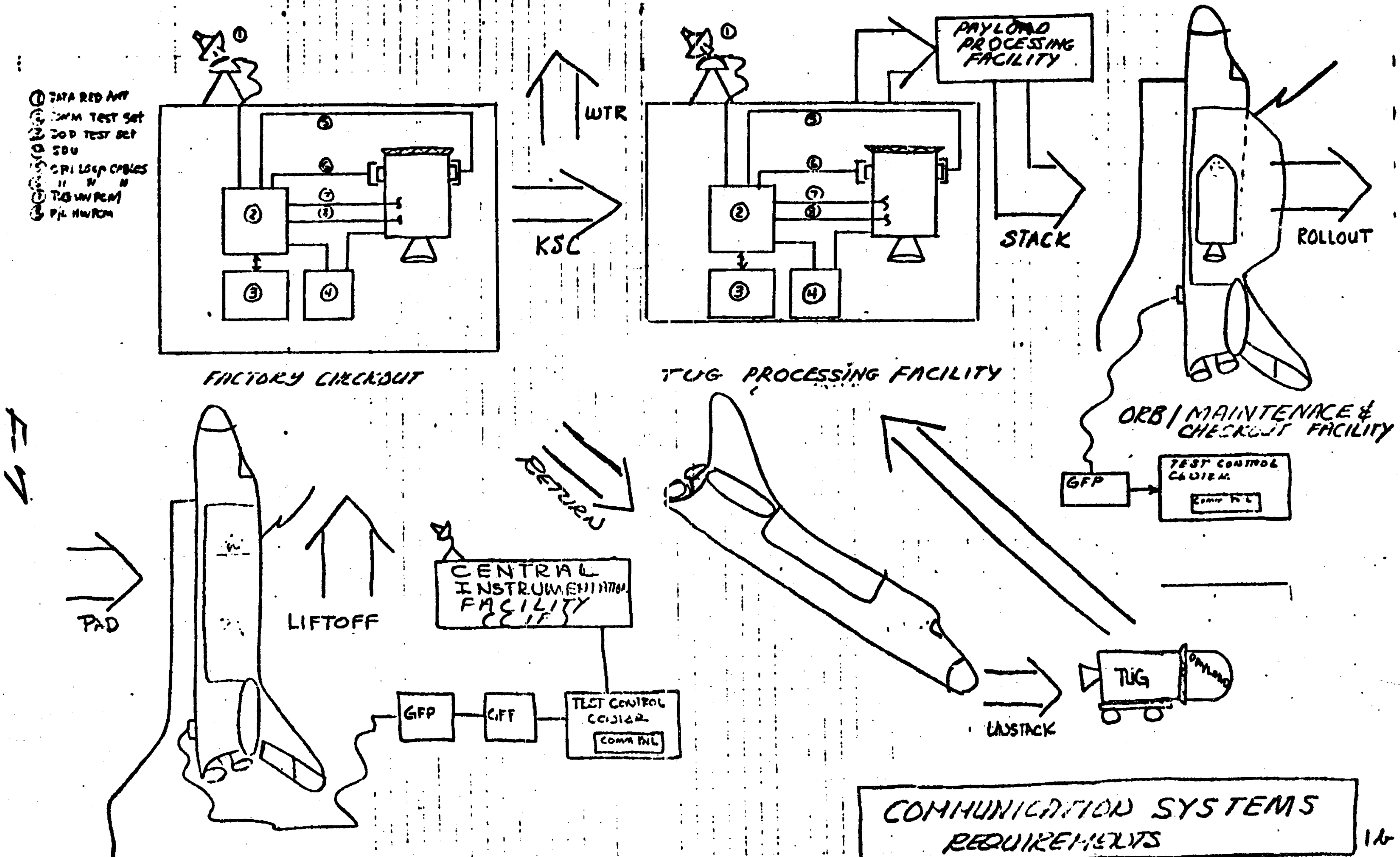
TABLE OF CONTENTS
(CONT.)

TABLE OF CONTENTS
(CONT.)

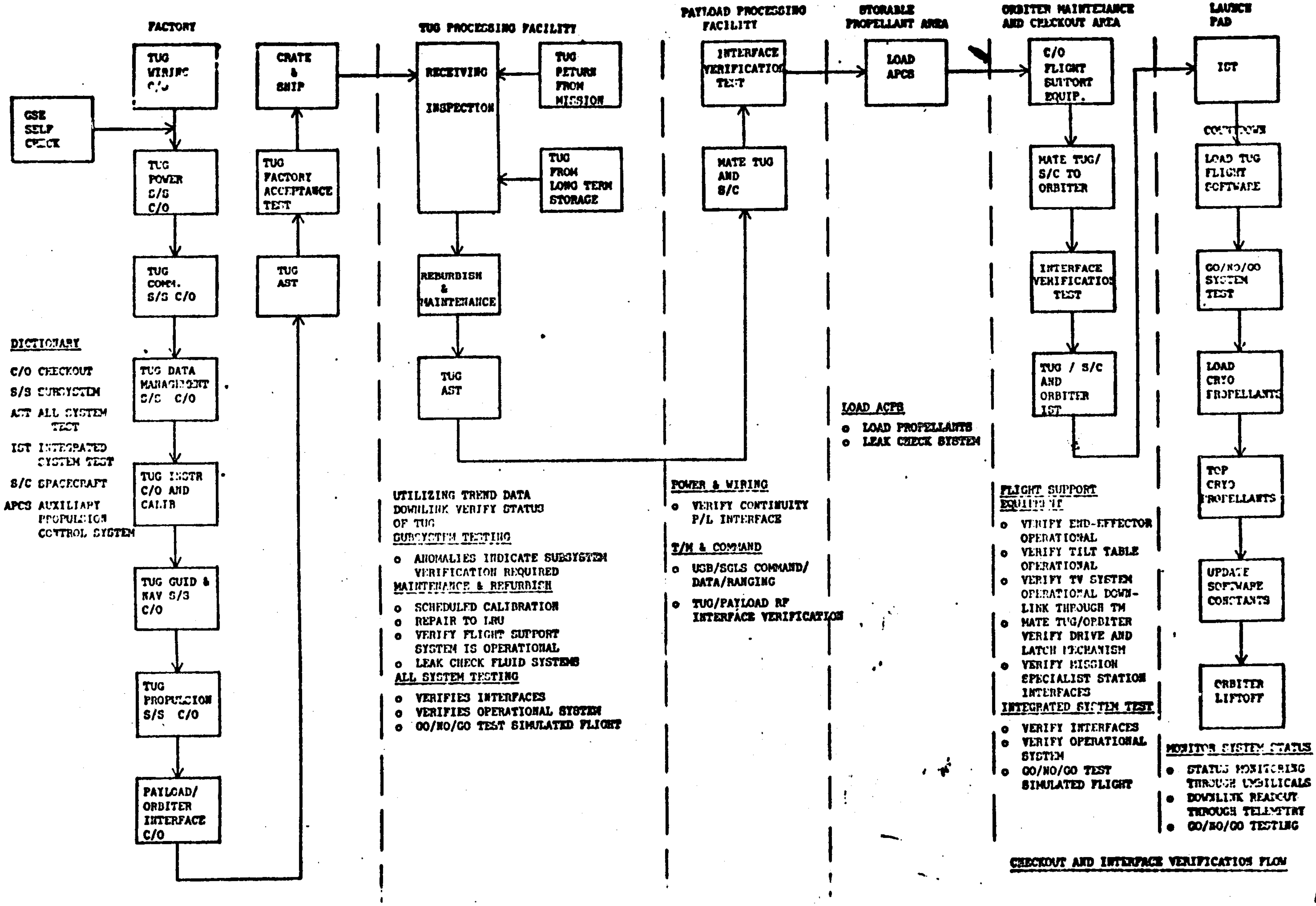
TABLE OF CONTENTS
(CONT.)


DEVELOPMENT SCHEDULE
OPTION 3
1976
1977
1978
1979
1980
S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O
ENGINEERING
DEVELOPMENT FIXTURE
FAB & ASSY
DEV PLUMBING WIRE/H & UPGRADE D.F.
MAINTENANCE PROCESS VERIF. & EVALUATION
PROPELLANT TANKS PRESSURE CYCLING DEVELOPMENT TEST
LO_2 TANK AVAIL
LH_2 TANK AVAIL
TEST REQMTS PLNG & FIXT DESIG
SETUP & TEST
TEARDOWN, ANALYSIS & REPORT
PROPELLANT TANKS PRESSURE BURST DEVELOPMENT TEST
LO_2 TANK AVAIL
LH_2 TANK AVAIL
TEST REQMTS PLNG & FIXT DESIGN
SETUP & TEST
TEARDOWN, ANALYSIS & REPORT
PROPELLANT TANKS PRESSURE CYCLING & PROOF PRESSURE QUALIFICATION TEST
LO_2 TANK AVAIL
LH_2 TANK AVAIL
TEST REQMTS PLNG & FIXT DESIGN
(FROM CYCLE TEST)
SETUP & TEST
TEARDOWN, ANALYSIS & REPORT
FTV/TEST
HDWE AVAIL
TEST FIXT DES FACILITY PREP REQMTS & PLNG
TEST SETUP & PERFORMANCE
TEARDOWN, ANALYSIS &REPORT
INTEGRATED AVIONICS TEST UNIT TEST
TEST FIXT DES TEST PLNG & PREPARATION
SETUP & TEST
FAB & ASSY IATU GSE
TEARDOWN, ANALYSIS & REPORT
FLIGHT CONTROL SIMULATION
TEST FIXT DES TEST PLNG & PREPARATION
SETUP & TEST
TEARDOWN, ANALYSIS & REPORT
TUG/ORBITER FLIGHT SUPPORT EQUIPMENT TEST (WITHOUT IVU)
HDWE AVAIL
TEST PLNG FIXTURE DESIGN & PREP
SETUP & TEST
TEST PLNG, FIXTURE DESIGN & PREP
TUG/ORBITER FLIGHT SUPPORT EQUIPMENT TEST (WITH IVU)
HDWE AVAIL
TEST FIXTURE DESIGN TEST PLNG & PREPARATION
SETUP & TEST
TEARDOWN, ANALYSIS & REPORT
FLIGHT TEST OPERATIONS
VEHICLE AVAIL
FLIGHT TEST PLANNING
LAUNCH OPS SUPT
FLIGHT TESTS
ANALYSIS & REPORT
FLIGHT SOFTWARE
DESIGN
MECHANIZATION
SOFTWARE ACCEPTANCE TESTING
GROUND SUPPORT EQUIPMENT
FAB ASSY & TEST PROTO AVIONIC GRD SUPPORT EQUIP
ENGINEERING
FAB. ASSY & CHECKOUT AVIONIC GSE
C/O AVIONICS SOFTWARE INTEG
C/O EQUIP SOFTWARE ACCEPT. TESTING
SOFTWARE MECHANIZATION
CHECKOUT & SUPPORT GSE S/W PROC. DESIGN
GSE & FLIGHT COMPUTER C/O EXEC. & COMPILER
MECHNNIZATION OF SOFTWARE
GSE & FLT COMPUTER C/O EXEC./COMPILER DESIGN
SYMBOLOGY
VEHICLE DEL
MILESTONE
IOC
ACTIVITY

12



COMMUNICATION SYSTEMS REQUIREMENTS

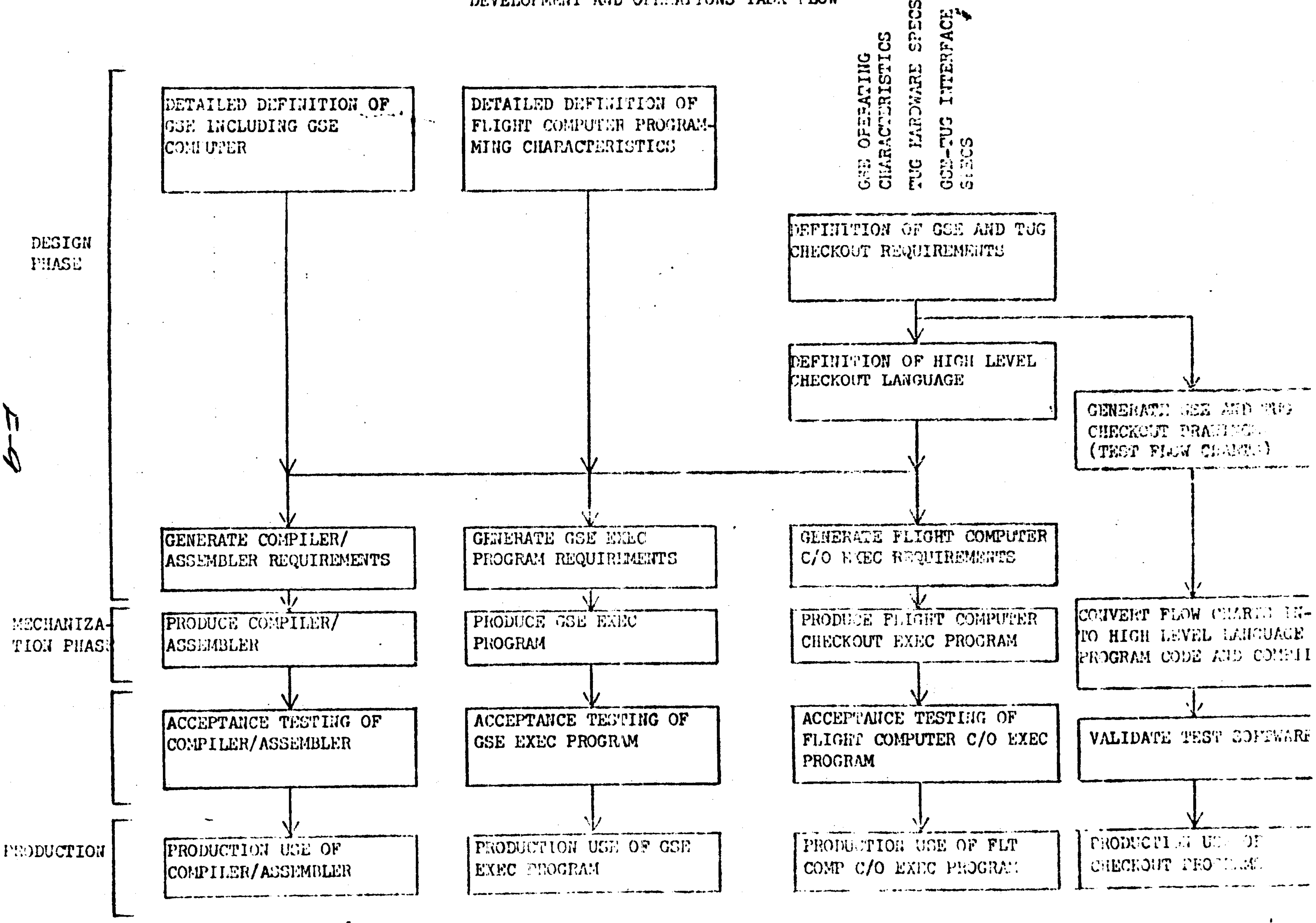


CHECKOUT AND INTERFACE VERIFICATION FLOW

1c

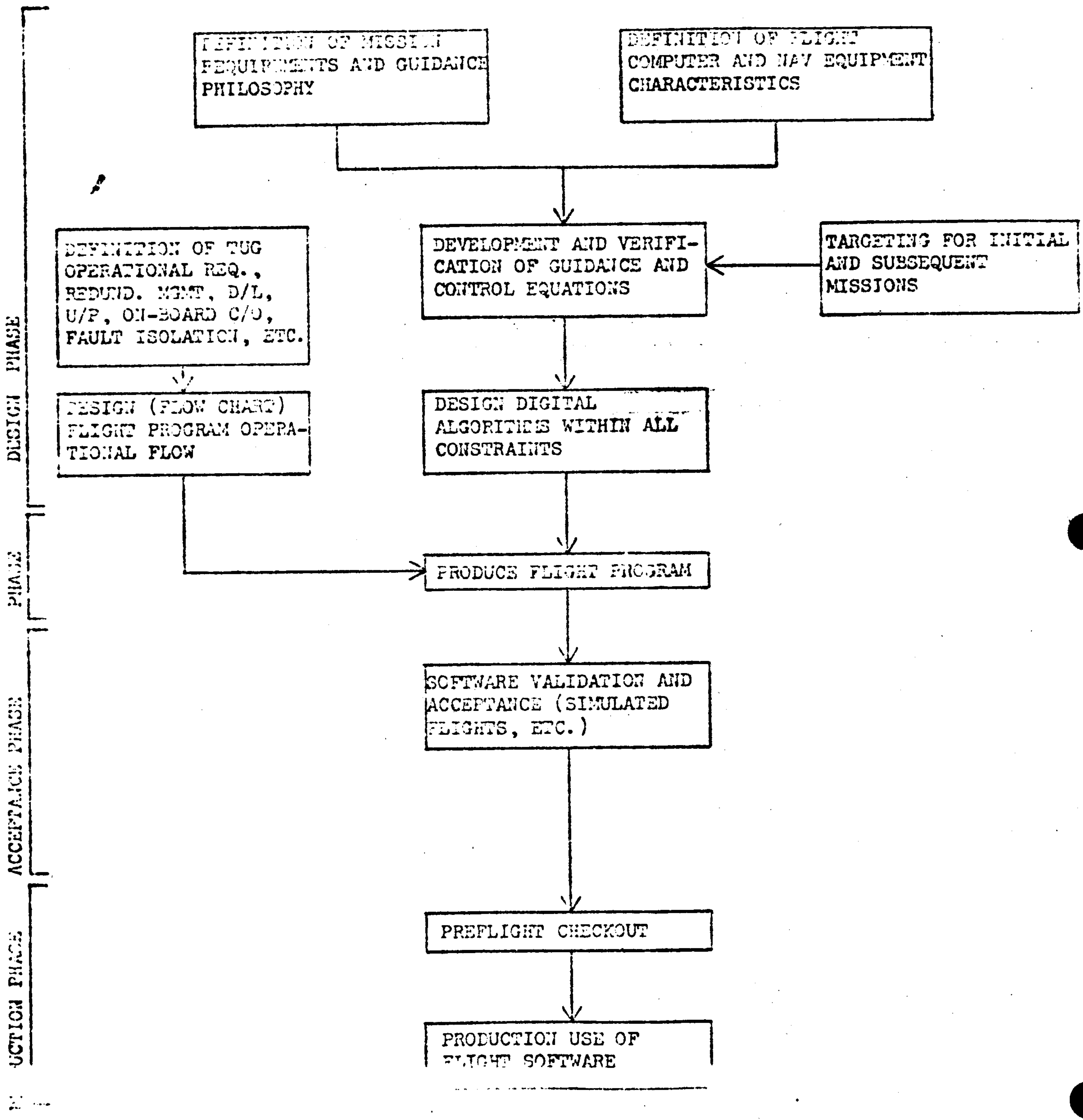
CHECKOUT SOFTWARE

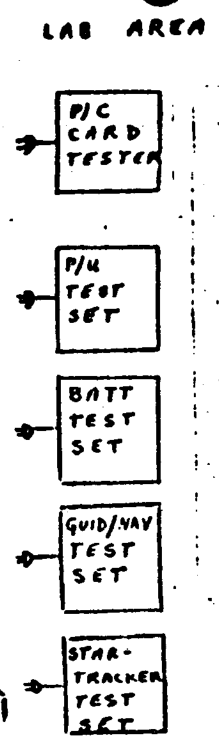
DEVELOPMENT AND OPERATIONS TASK FLOW

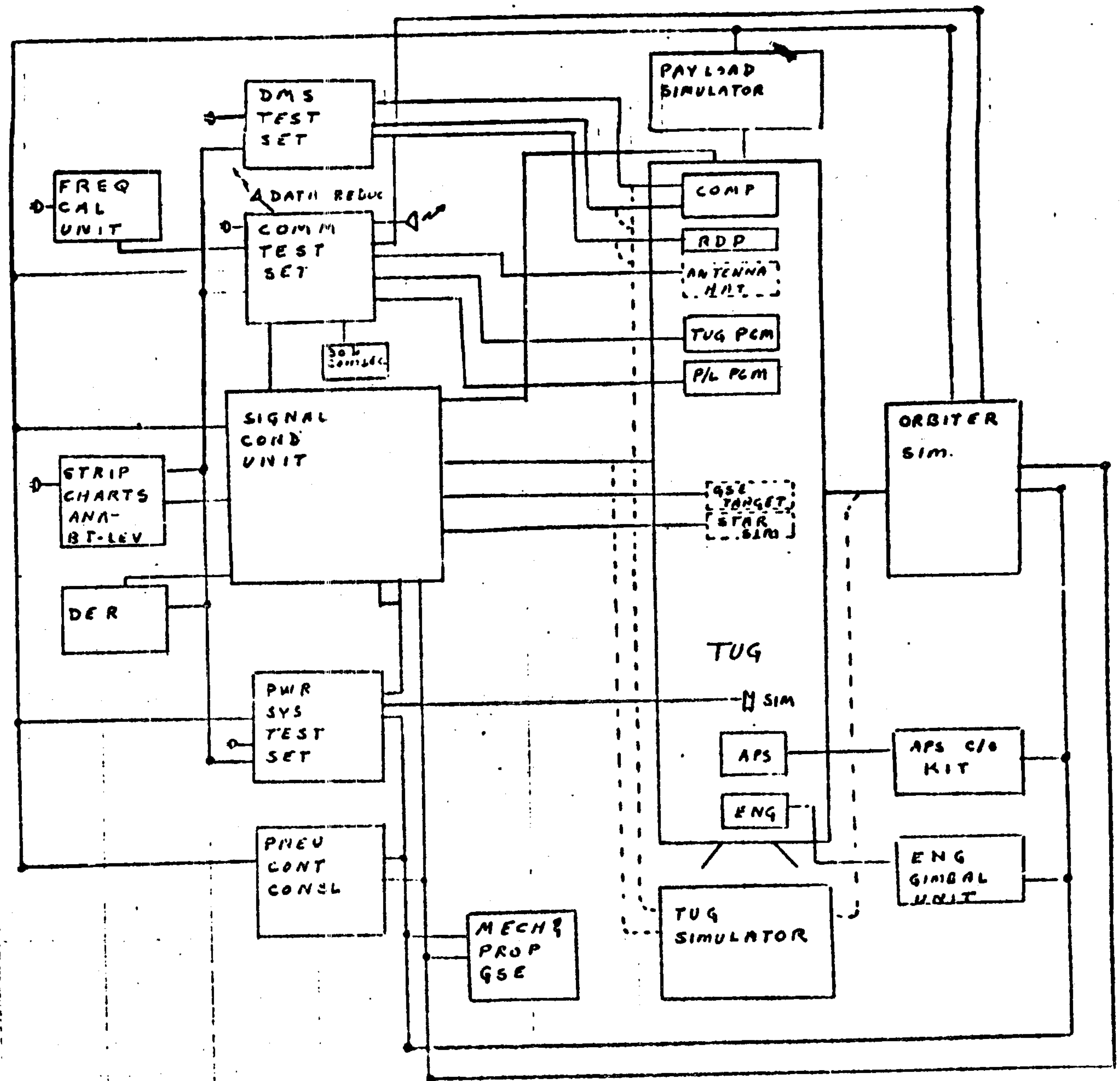


FLIGHT SOFTWARE

DEVELOPMENT AND OPERATIONS TASK FLOW



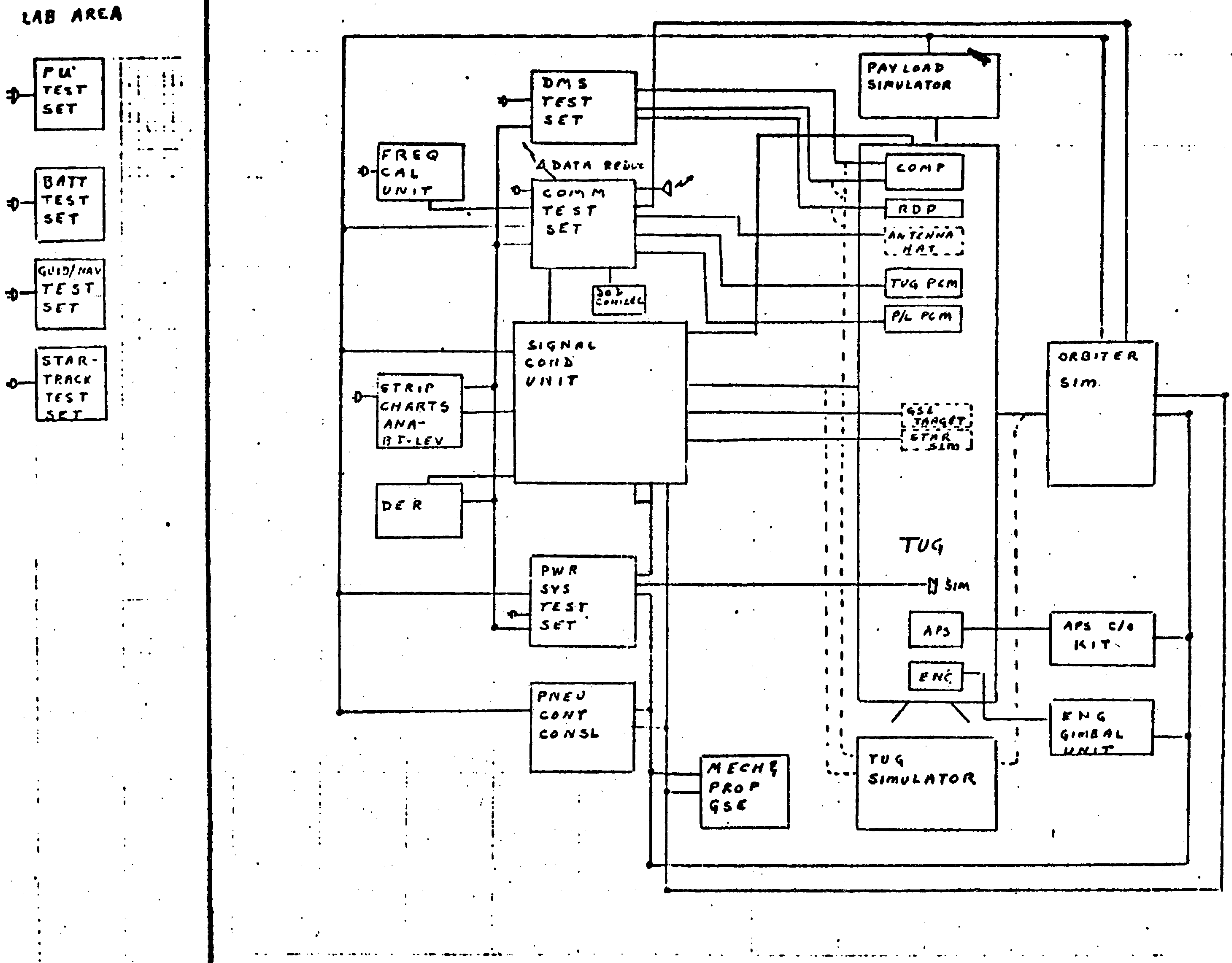




FACTORY CHECKOUT

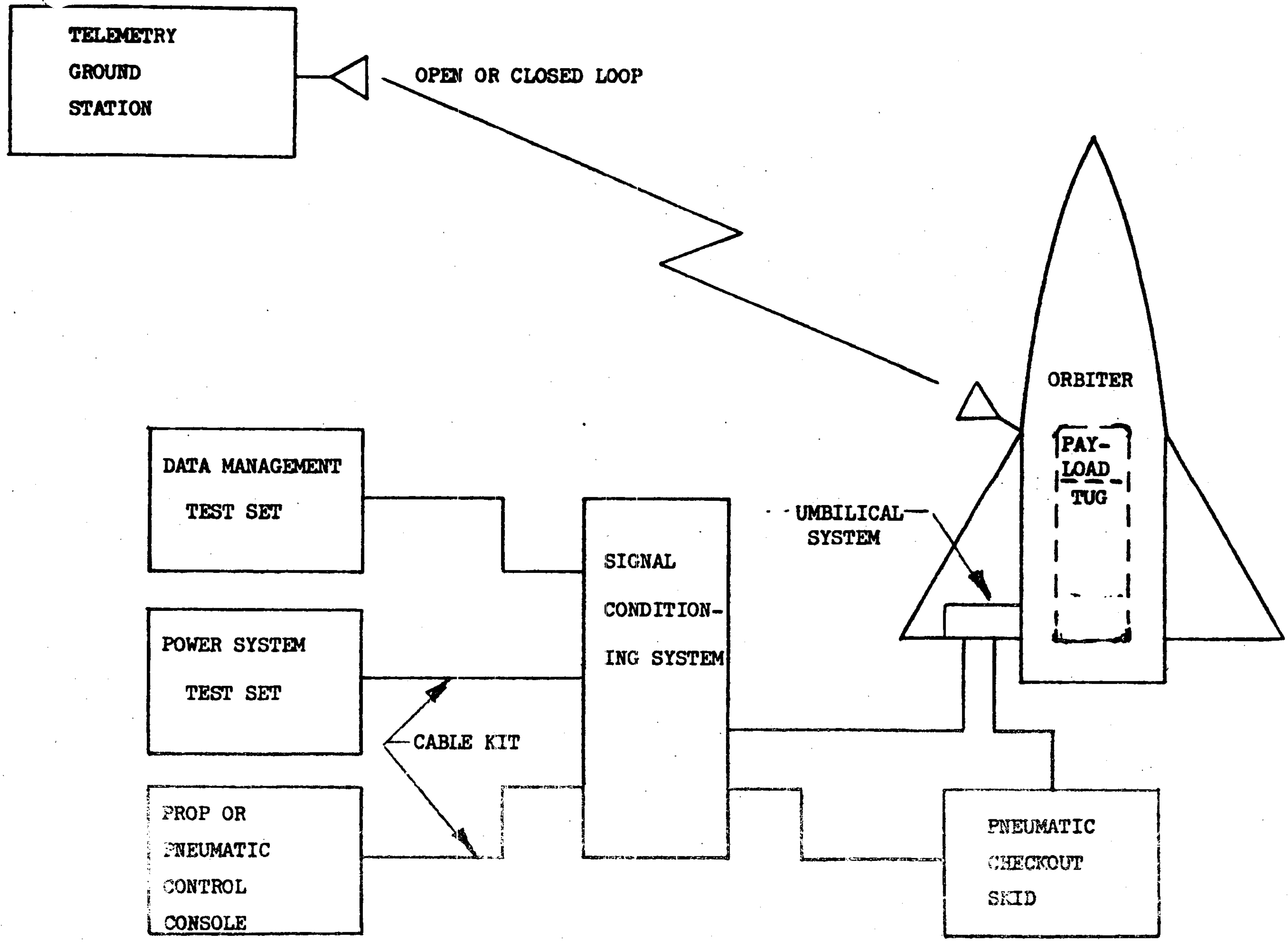
E-11

14

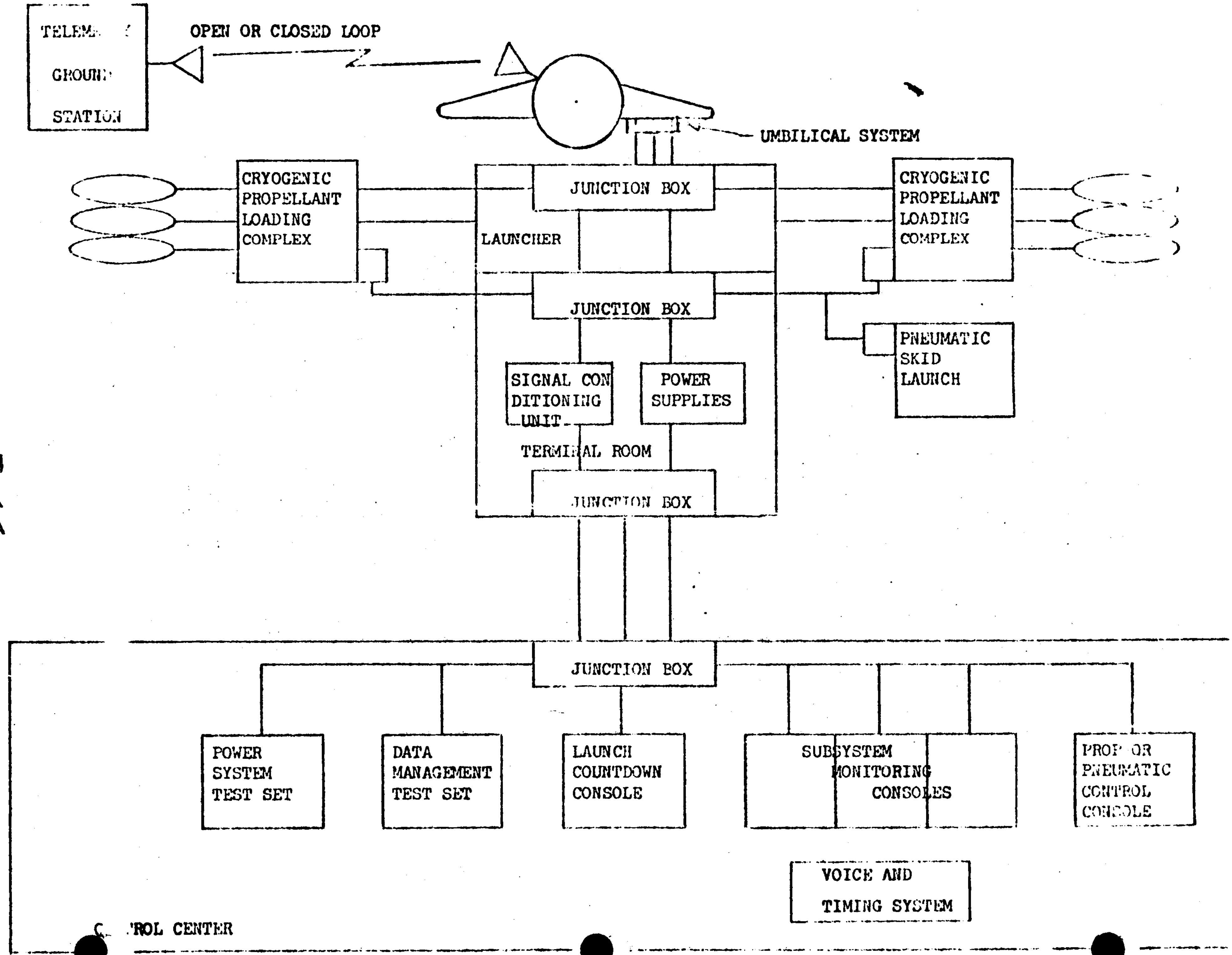


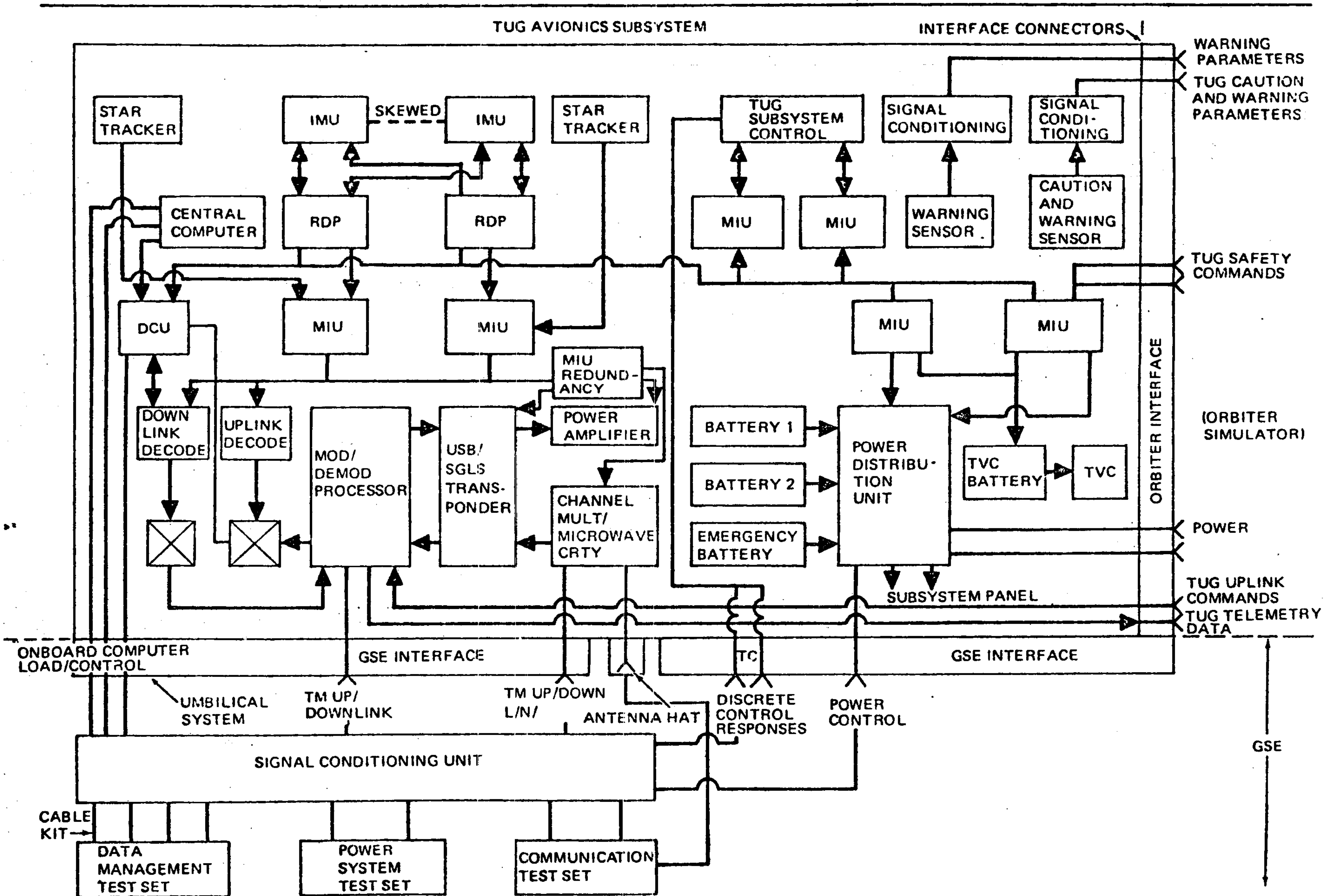
TUG PROCESSING FACILITY

19

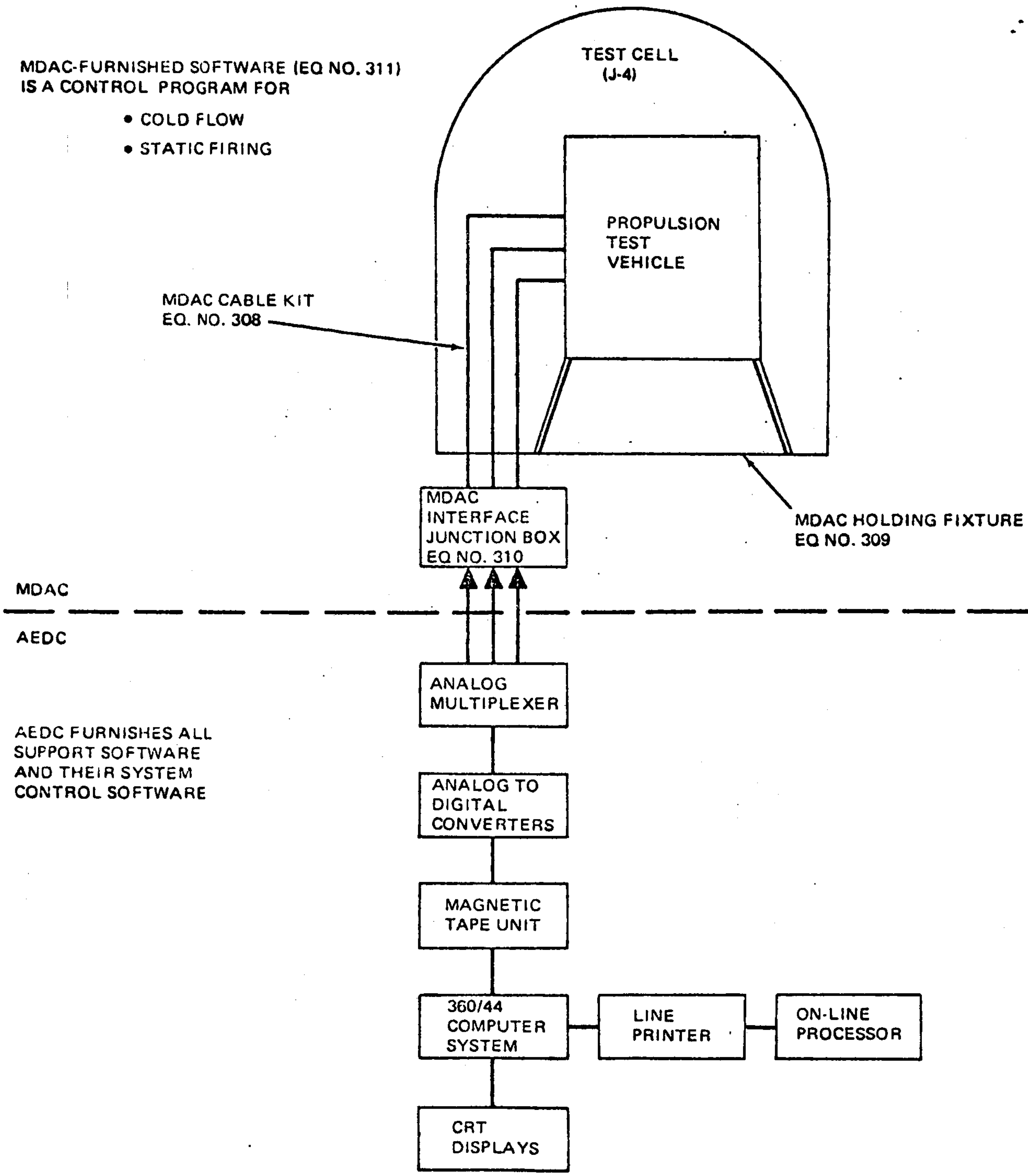


ORBITER MAINTENANCE AND CHECKOUT FACILITY


TELEM
GROUND
STATION
OPEN OR CLOSED LOOP
UMBILICAL SYSTEM
CRYOGENIC PROPELLANT LOADING COMPLEX
JUNCTION BOX
LAUNCHER
JUNCTION BOX
CRYOGENIC PROPELLANT LOADING COMPLEX
PNEUMATIC SKID LAUNCH
SIGNAL CONDITIONING UNIT
POWER SUPPLIES
TERMINAL ROOM
JUNCTION BOX
JUNCTION BOX
POWER SYSTEM TEST SET
DATA MANAGEMENT TEST SET
LAUNCH COUNTDOWN CONSOLE
SUBSYSTEM MONITORING CONSOLES
PROP OR PNEUMATIC CONTROL CONSOLE
VOICE AND TIMING SYSTEM
ROL CENTER

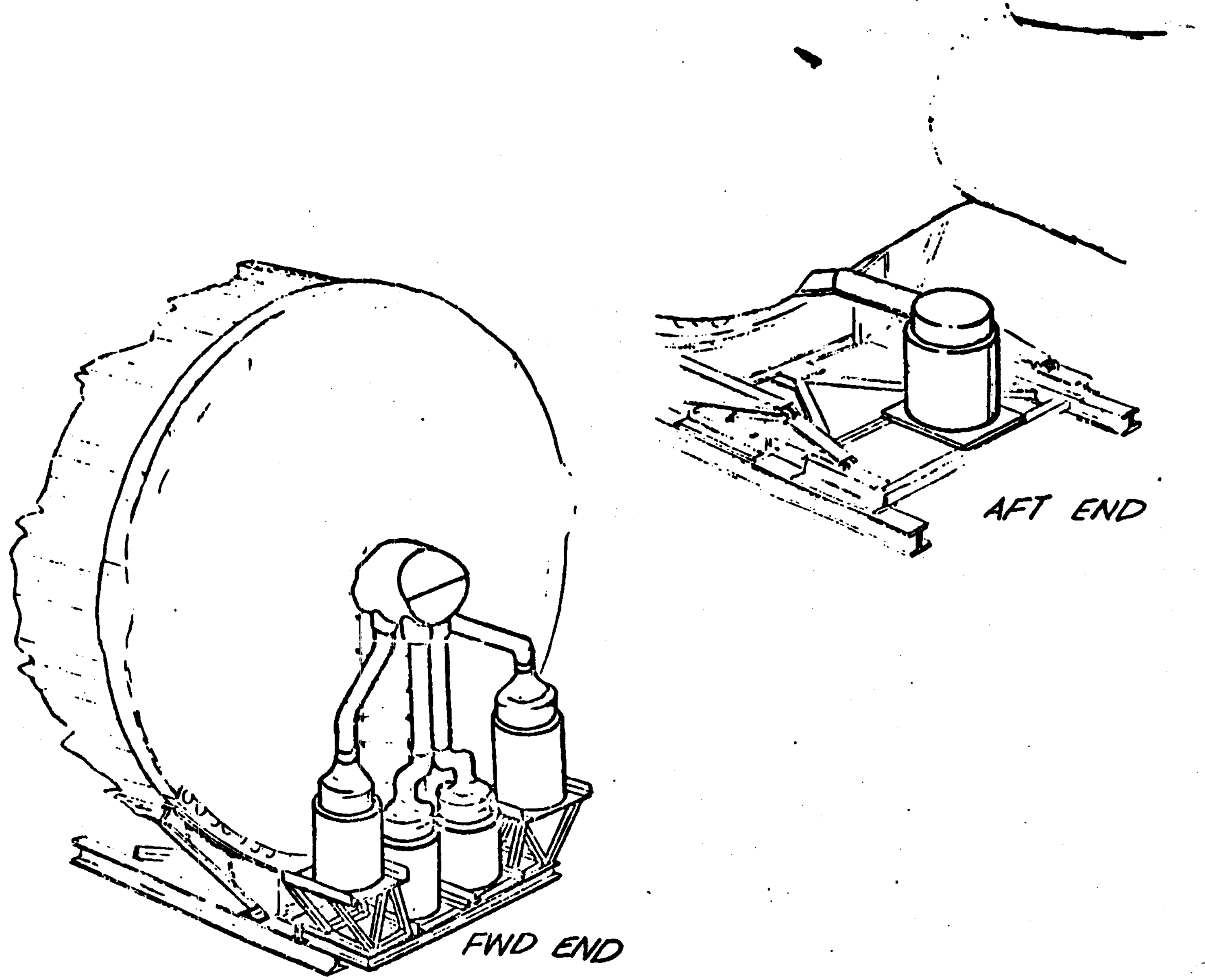


Integrated Avionics Test Unit



. Propulsion Test Vehicle/Ground Support Equipment Assembly

1 ke



Environmental Kit, Air Carry – VPG

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: AIR CARRY ENVIRONMENTAL KIT -- VPG EQUIPMENT NO. 104

FUNCTIONAL REQUIREMENT(S):

Maintains the stage fuel and LOX tanks and the propulsion subsystems in a clean dry condition during transportation in the Super Guppy.

EQUIPMENT DESCRIPTION:

Similar to DSV-4B-1862

COST $ 1200 (DESIGN AND DEVELOPMENT)

$ 2400 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED 10% AS IS 90%

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.4	KSC	1

TOTAL REQUIRED 1 TOTAL COST $ 3600

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: AIR CARRY ENVIRONMENTAL KIT -- VPG EQUIPMENT NO. 105

FUNCTIONAL REQUIREMENT(S):

Maintains the stage fuel and LOX tanks and the propulsion subsystems in a clean dry condition during transportation in the Super Guppy.

EQUIPMENT DESCRIPTION:

Utilize DSV-4B-1862 (GFE)

COST $ 0 (DESIGN AND DEVELOPMENT)

$ 0 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED ______ AS IS 100%

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.4	KSC	1

TOTAL REQUIRED 1 TOTAL COST $ -0-

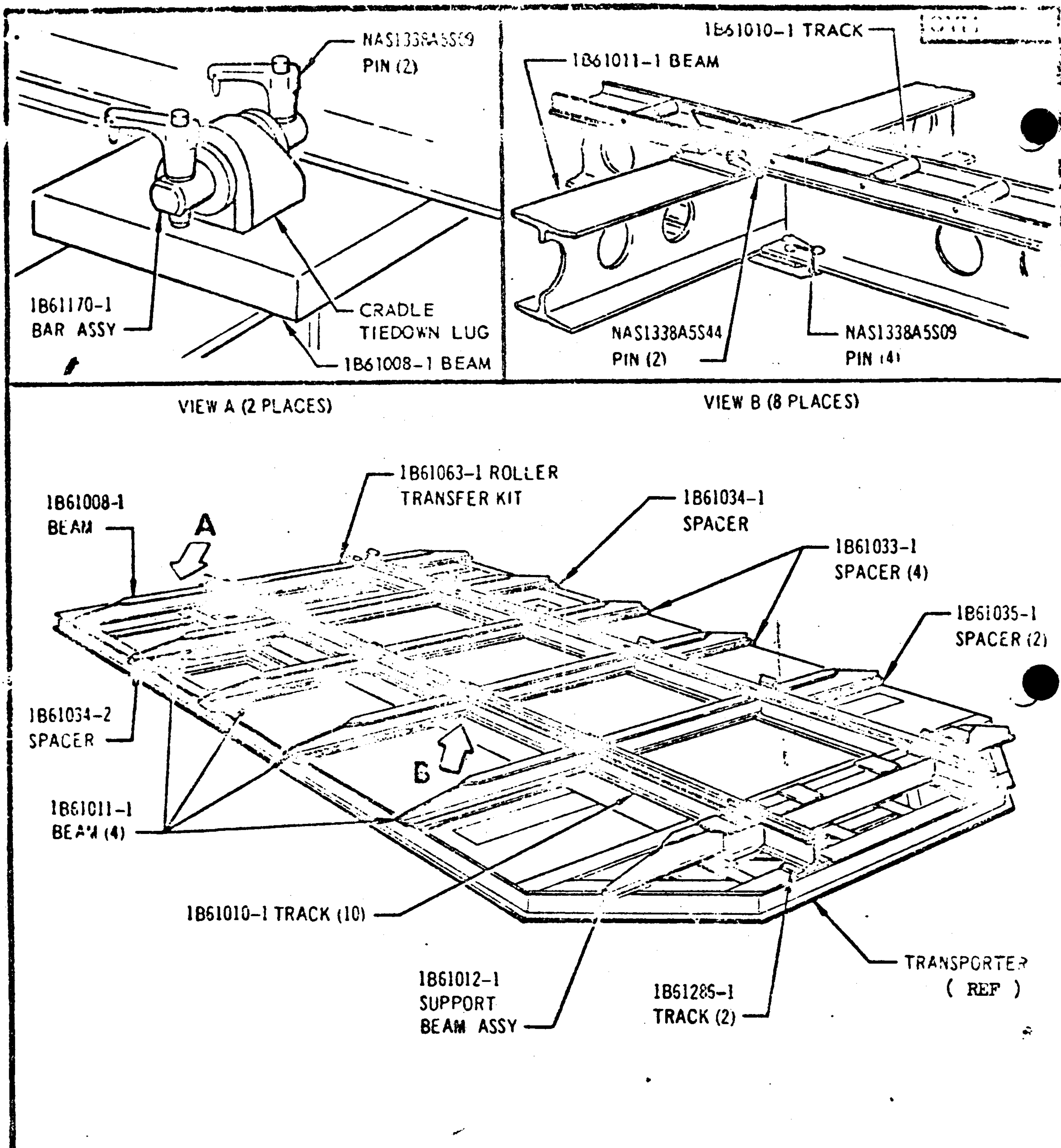


FIGURE 1.
ROLLER TRANSFER KIT

CODE IDENT NO.	SIZE
18355	A

SHEET

CONFIGURATION OPTION

GSE DESCRIPTION SHEET

NAME: AIR CARRY ROLLER TRANSFER KIT -- VPG EQUIPMENT NO. 106

FUNCTIONAL REQUIREMENT(S):

Provides the means of adapting the transporter to facilitate the transfering of the stage when the stage is shipped by Super Guppy.

EQUIPMENT DESCRIPTION:

Utilize DSV-4B-1863 (GFE)

COST $ -0- (DESIGN AND DEVELOPMENT)

$ -0- (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW X MODIFIED ____ AS IS X

1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.4	KSC	1
	WTR	1

TOTAL REQUIRED 2 TOTAL COST $ -0-

E-21

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: AIR CARRY SUPPORT -- VPG   EQUIPMENT NO. 107

FUNCTIONAL REQUIREMENT(S):

Provides support for stage during all transportation modes.

EQUIPMENT DESCRIPTION:

Similar to DSV-4B-1859

COST $ 20,000 (DESIGN AND DEVELOPMENT)

$ 15,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW ________ MODIFIED 50% AS IS 50%

1ST YEAR REQ'D ________ NUMBER AVAILABLE ________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.4	KSC	1
	WTR	1

TOTAL REQUIRED 2   TOTAL COST.... $ 50,000

E-22

SYM

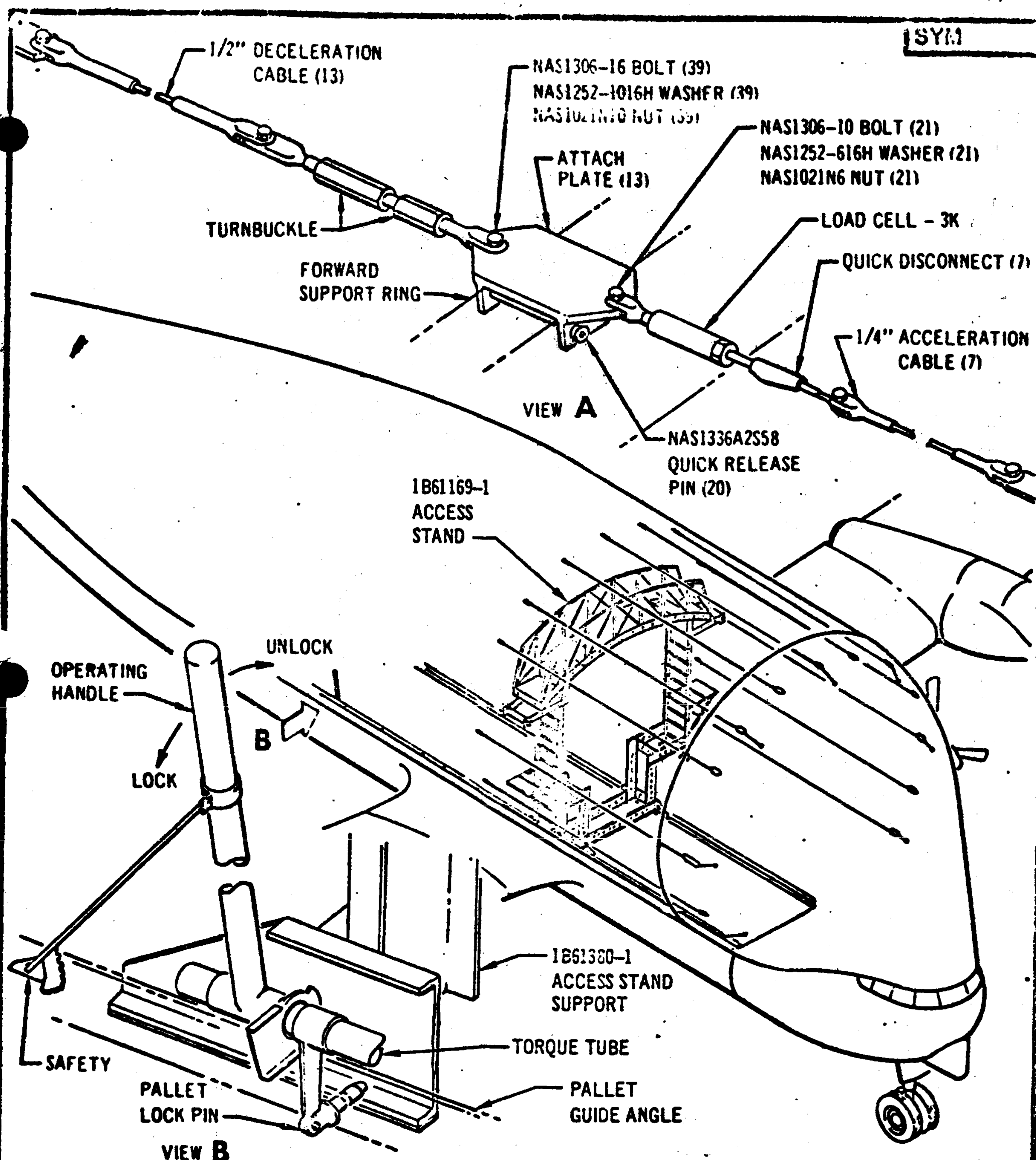


FIGURE 11

CODE IDENT NO.	SIZE	
18355	A	AIR CARRY TIE DOWN KIT VPG

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: AIR CARRY TIE DOWN KIT — VPG EQUIPMENT NO. 108

FUNCTIONAL REQUIREMENT(S):

Secures stage inside Super Guppy and protects it from undue acceleration and deceleration inertia.

EQUIPMENT DESCRIPTION:

Similar to DSV-4B-1861

COST $ 4000 (DESIGN AND DEVELOPMENT)

$ 2500 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

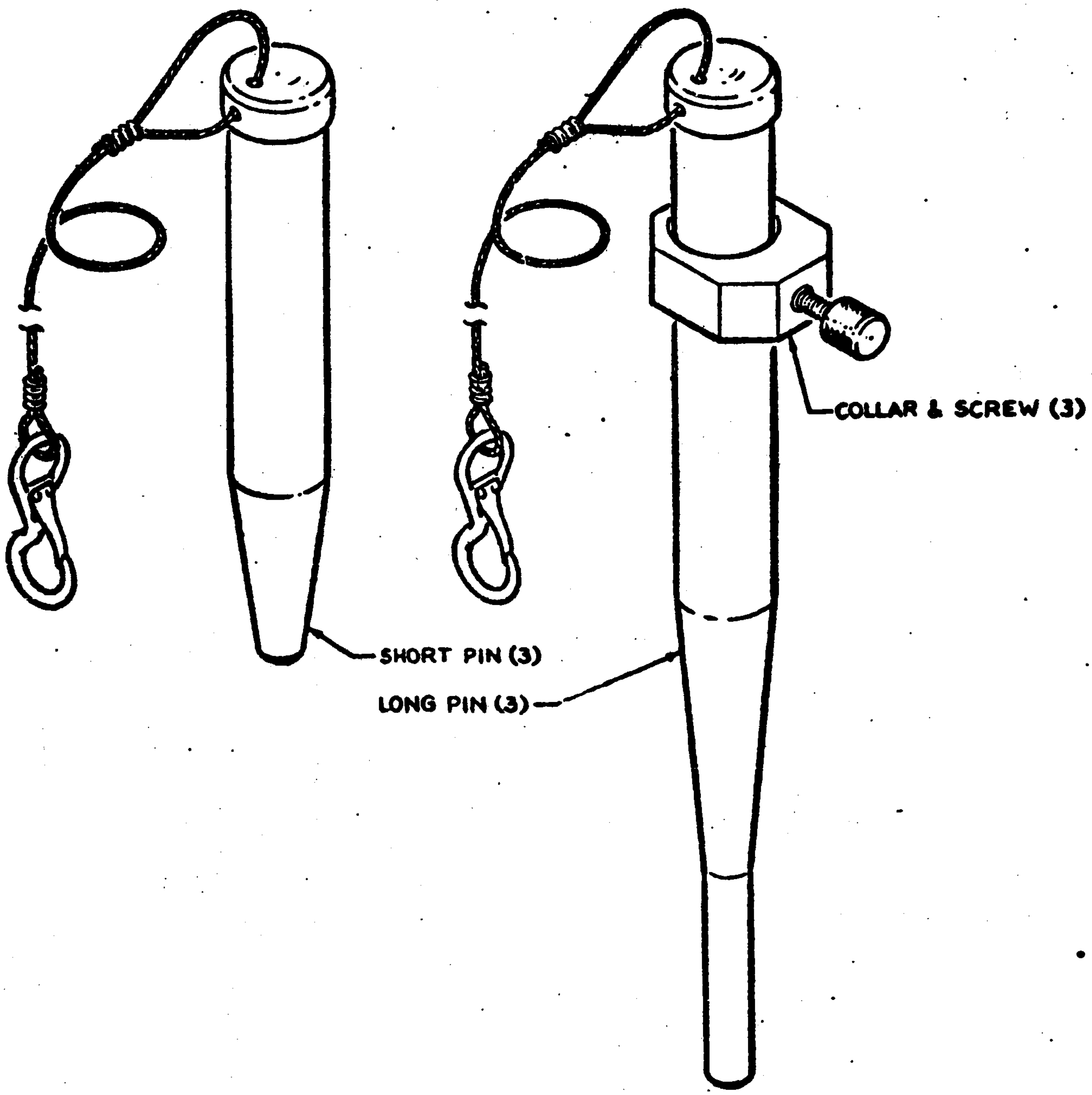
NEW X MODIFIED ______ AS IS ______

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.4	KSC	1

TOTAL REQUIRED 1 TOTAL COST $ 6500



Alignment Kit,

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: ALIGNMENT KIT EQUIPMENT NO. 110

FUNCTIONAL REQUIREMENT(S):

Provides necessary hardware for alignment, installation, and staging to the spacecraft.

EQUIPMENT DESCRIPTION:

Similar to DSV-4B-340

COST $ 7200 (DESIGN AND DEVELOPMENT)

$ 3300 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW x MODIFIED ______ AS IS ______

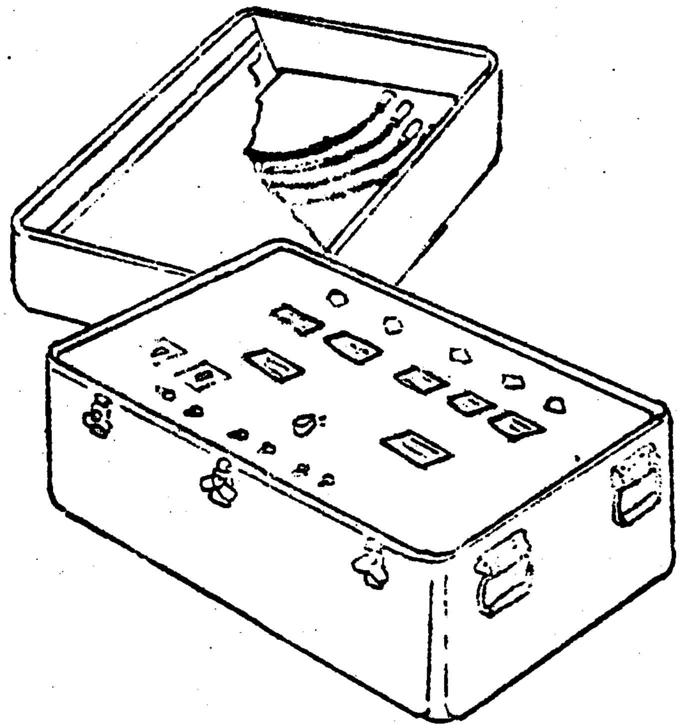
1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
	TPF/KSC	1
	PPF/KSC	1
	PPF/WTR	1

TOTAL REQUIRED 3 TOTAL COST $ 17,100

E-26



APS BREAKOUT CONTROL BOX

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: APS BREAKOUT CONTROL BOX EQUIPMENT NO. 111

FUNCTIONAL REQUIREMENT(S):

Provides individual electrical control of the APS thruster valves and isolation valves for checkout.

EQUIPMENT DESCRIPTION:

Twelve cable assemblies, suitcase assembly which contains one momentary sw., five push button indicator sw., one toggle sw., six indicator lamps, two circuit breakers, one six-bank wafer sw., five fuxes, twelve connectors, and associated wiring. (Similar to DSV-7-106).

COST $ 500 (DESIGN AND DEVELOPMENT)

$ 250 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW X MODIFIED 50% AS IS 50%

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
New Checkout and 1.1.11	TPF/KSC	1
New Checkout and 1.1.11	PPF/WTR	1
	Factory	1

TOTAL REQUIRED 3 TOTAL COST $ 1,250

E-28

GSE DESCRIPTION SHEET

NAME: APS LOADING ACCESSORIES KIT EQUIPMENT NO. 112

FUNCTIONAL REQUIREMENT(S):

To adapt APS servicer to vehicle and provide miscellaneous tools and equipment required for storable APS loading.

EQUIPMENT DESCRIPTION:

Collection of hoses, tools, and other equipment for use in APS loading and unloading operations.

COST $ 1000 (DESIGN AND DEVELOPMENT)

$ 2000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW X MODIFIED ______ AS IS ______

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.1.7	Storable/KSC	1
	Storable/WTR	1
	Factory	1

TOTAL REQUIRED 3 TOTAL COST $ 7,000

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: APS SERVICER EQUIPMENT NO. 113

FUNCTIONAL REQUIREMENT(S):

Provide purging, loading, and unloading of storable APS propellant systems.

EQUIPMENT DESCRIPTION:

Modification to existing Saturn APS servicer.

COST $ 500 (DESIGN AND DEVELOPMENT)

$ 2000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW ________ MODIFIED X AS IS ________

1ST YEAR REQ'D ________ NUMBER AVAILABLE ________

EQUIPMENT UTILIZATION:

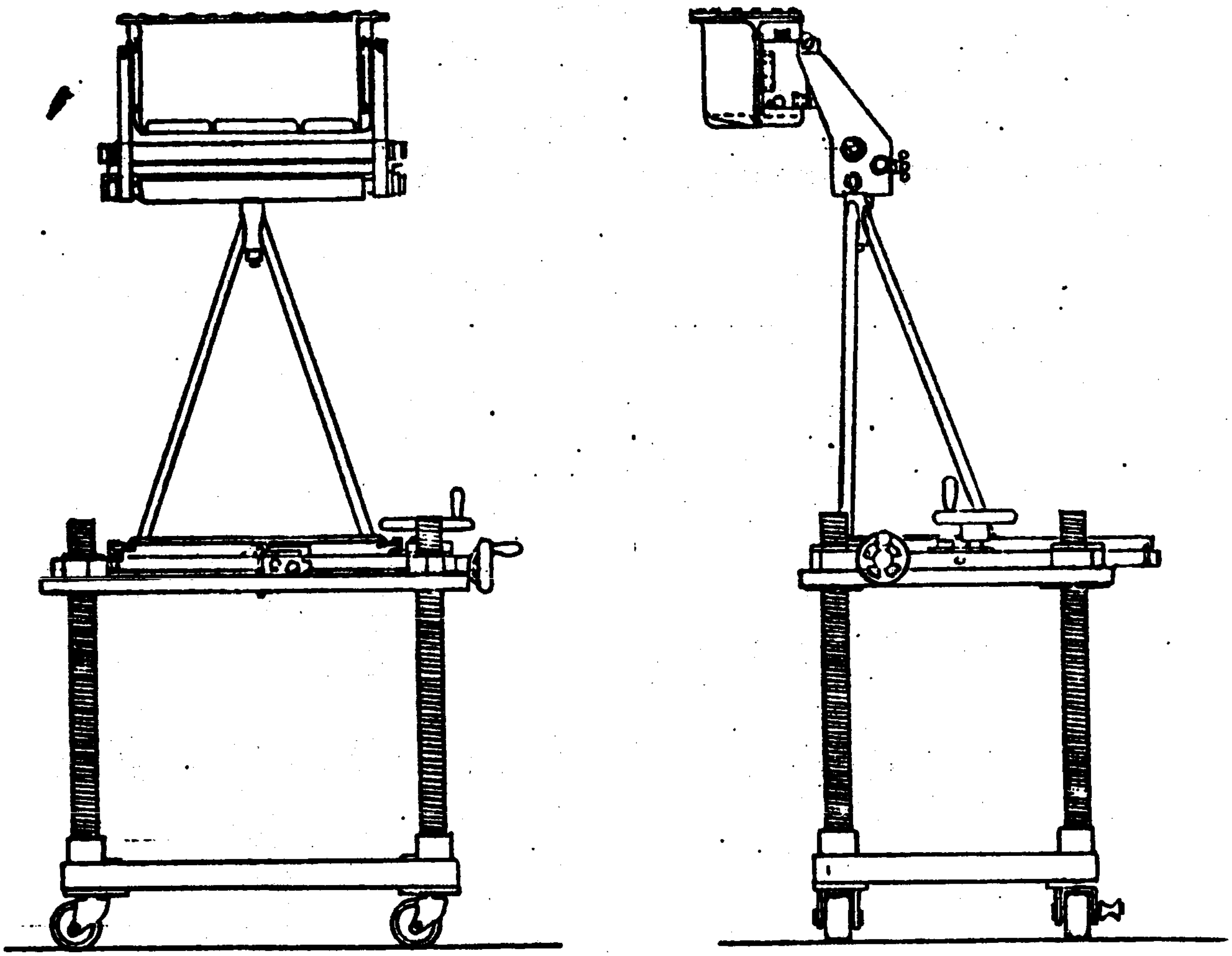
FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.1.7	Storable/KSC	1
	Storable/WTR	1

TOTAL REQUIRED 2 TOTAL COST $ 5,000

E-30

FORM X60-999-3 (10-62)

SYM



CODE IDENT NO.	SIZE	
18355	A	BATTERY HANDLING KIT

SHEET

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: BATTERY HANDLING KIT EQUIPMENT NO. 115

FUNCTIONAL REQUIREMENT(S):

Provides installation of batteries in stage when in horizontal or vertical position.

EQUIPMENT DESCRIPTION:

Similar to DSV-4B-400

COST $ 10,000 (DESIGN AND DEVELOPMENT)

$ 2,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED 5% AS IS 95%

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.20	TPF/KSC	1
	PPF/WTR	1

TOTAL REQUIRED 2 TOTAL COST $ 14,000

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: CHECKOUT ACCESSORIES KIT EQUIPMENT NO. 117

FUNCTIONAL REQUIREMENT(S):

Assembles miscellaneous equipment required for test and checkout.

EQUIPMENT DESCRIPTION:

Collection of hoses, gage-regulator assemblies, fittings, leak test equipment, test plates, flow meters, and other miscellaneous checkout equipment.

COST $ ______ (DESIGN AND DEVELOPMENT)

$ 3000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED X AS IS ______

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.7.1	KSC	4
	WTR	4

TOTAL REQUIRED 8 TOTAL COST $ 24,000

GSE DESCRIPTION SHEET

NAME: CHECKOUT CABLE KIT EQUIPMENT NO. 118

FUNCTIONAL REQUIREMENT(S):

Provides interconnects between test sets, vehicle, power, etc.

EQUIPMENT DESCRIPTION:

Consists of all cable, (power, RF, signal) required to support Tug Unique checkout in all areas. Cable network - 70 cable assemblies (80 ft) long - (35 60 pin cables; (18) 4 pin cables; (5) 39 pin cables; 7 coax cables; (5) 24 pin cables; breakout cables and general breakout box. Similar to DSV-4B-726A.

COST PER UNIT: $ 13,500 (DESIGN AND DEVELOPMENT)

$ 5,100 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

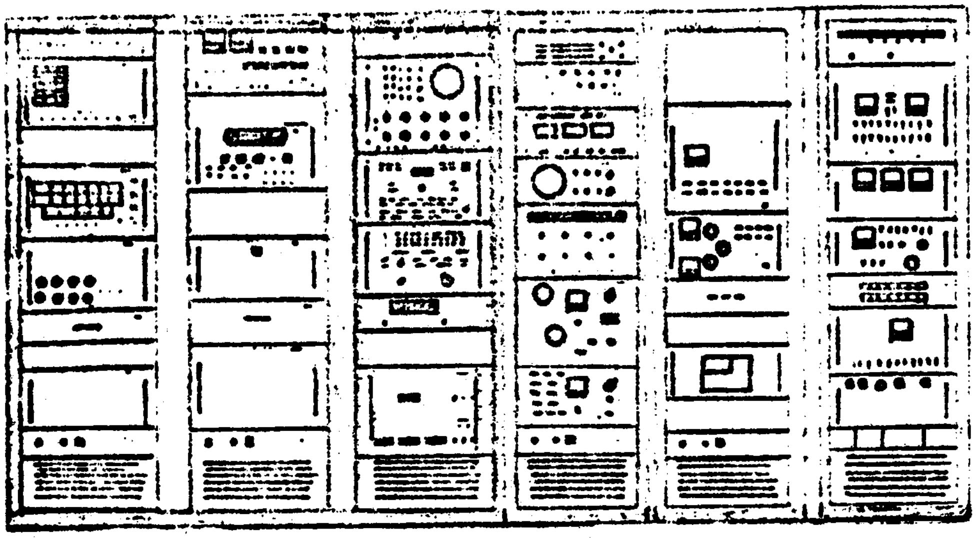
NEW s MODIFIED 30% AS IS

1ST YEAR REQ'D NUMBER AVAILABLE

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.5, 1.1.7 ALL	KSC	5 5
1.1.8 ALL	WTR	4
1.1.9 ALL	Factory	1
1.1.14		
2.3.9, 2.4.2		

TOTAL REQUIRED 10 TOTAL COST $ 64,500



COMMUNICATION SYSTEM TEST SET

GSE DESCRIPTION SHEET

NAME: COMMUNICATION SYSTEM TEST SET EQUIPMENT NO. 119

FUNCTIONAL REQUIREMENT(S):

Receives, demodulates PCM data from spacecraft, provides for output to computer storage, contains display for visual data monitoring of incoming signals and routing of data to external areas for further processing. Can be controlled locally or through computer.

EQUIPMENT DESCRIPTION:

See attachment.

COST PER UNIT: $ 634,000 (NON-RECURRING)

$ 533,000 (RECURRING/YEAR)

EQUIPMENT CATEGORY:

NEW X MODIFIED ____ AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.8.9	TPF/KSC	1
1.1.9.9	PPF/WTR	1
	Factory	1

TOTAL REQUIRED 3 TOTAL COST $ 2,766,000

EQUIPMENT DESCRIPTION

NOMENCLATURE	QTY	FACTORY	LAUNCH	DE-ORBIT	REMARKS
X-Y Recorder	1	X		*	*Equipment to be
Sweep Oscillator	1	X		*	made available
Signal Generator	1	X		*	at launch complex
VSWR Meter	1	X		*	in the event of
RF Power Meter	1	X		*	transmission
~~RF~~ Misc. Equipment	TBD	X		*	failures.
Frequency Counter	1	X		X	Similar to DSV-
Frequency Converter	1				4B-123 and DSV-
S-Band Test Transmitter	2				4B-125
S-Band Test Receiver	2				
S-Band FM Receiver	1				
Payload PCM Demodulator	1				
SGLS/NASA PCM Demodulator	1				
PCM Decommutator	2				
PRN Ranging Assembly (SGLS/NASA)	2				
Error Rate Measuring Unit	1				
Command Signal Conditioner (SGLS/NASA)	2				
Regulated Power Supply	2				
Logic Power Supply	2				
PCM Simulator	1				
Oscilloscope	1				
Calibration Test Panel	1				
Manual Control Panel	1				
RF Switch Panel	1				
Source Selector Panel	1				
RF Attenuator Panel	1				
Quick Loop Panel	2				
Voice Communication Panel	3				
RMS Voltmeter	1				
Circuit Breaker Panel	2				
Patch Panel	1				
Analog Strip Chart	3				Similar to DSV-
Bilevel Strip Chart	3				4B-240, DSV-4B-
FM Oscillograph	2				238, DSV-4B-239
Digital to Analog Converters	80				
Galvanometer Drive Amplifiers	6				

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: COMPONENT PROTECTIVE COVERS **EQUIPMENT NO.** 120

FUNCTIONAL REQUIREMENT(S):

Provide prelaunch protection for vulnerable components. Removed prior to launch and returned to factory for re-use.

EQUIPMENT DESCRIPTION:

Protective covers for bellows, titanium bottles, and other components subject to ground handling damage, including G&C lens covers.

COST $ 2000 (DESIGN AND DEVELOPMENT)

$ 700 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW X MODIFIED ________ AS IS ________

1ST YEAR REQ'D ________ NUMBER AVAILABLE ________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.4	KSC	3
1.1.20	WTR	2

TOTAL REQUIRED 5 TOTAL COST $ 5,500

E-38

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: COMSEC EQUIPMENT EQUIPMENT NO. 121

FUNCTIONAL REQUIREMENT(S):

To decrypt telemetry from DoD spacecraft and Tug vehicle to the telemetry ground station. Also utilized to encrypt telemetry from the telemetry ground station to the on-orbit element.

EQUIPMENT DESCRIPTION:

GFE rack of EN/DECRYPT ENCRYPT EQUIP

COST $ 0 (DESIGN AND DEVELOPMENT)

$ 0 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED ______ AS IS X (GFE)

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
	KSC	2
	WTR	2

TOTAL REQUIRED 4 TOTAL COST $ 0.00

E-39

SYM

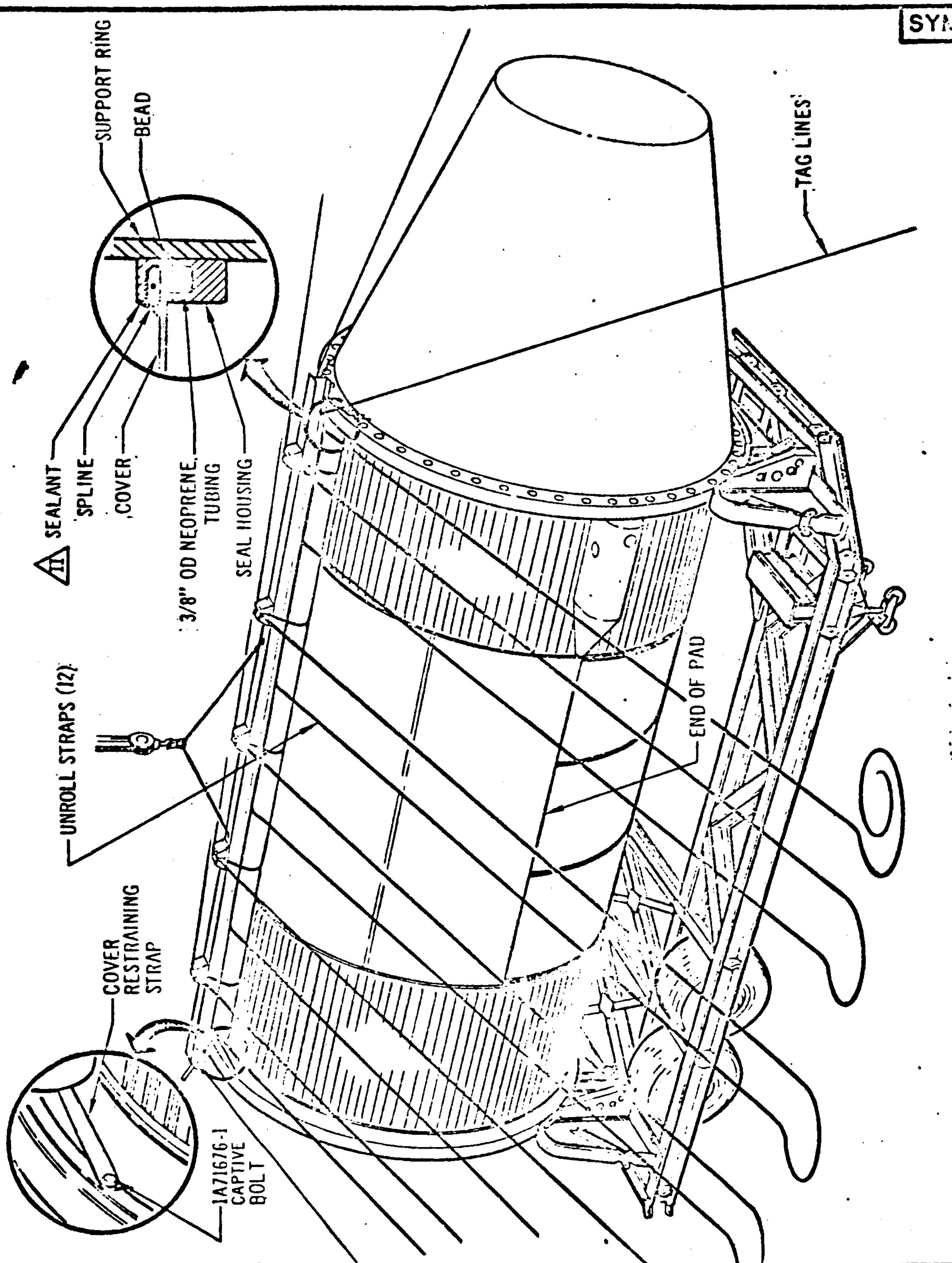


FIGURE 6
CENTER COVER INSTALLATION

CODE IDENT NO.	SIZE	
18355	A	COVERS - SPACECRAFT/TUG

E-40

SHEET

GSE DESCRIPTION SHEET

NAME: COVER - SPACECRAFT EQUIPMENT NO. /122

FUNCTIONAL REQUIREMENT(S):

To provide environmental and physical protection to a SC while it is joined to the Tug on the transporter.

EQUIPMENT DESCRIPTION:

A rubber impregnated fabric cover for the SC designed to integrate with the Tug cover as a replacement for its forward section.

COST PER UNIT: $ 3,000 (DESIGN AND DEVELOPMENT)

$ 500 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW X MODIFIED ____ AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE 0

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.4	KSC	4
1.1.2.1	WTR	1
1.1.2.6		
2.3.6		
2.4.8		

TOTAL REQUIRED 5 TOTAL COST $ 5,500

GSE DESCRIPTION SHEET

NAME: Cover-Tug EQUIPMENT NO. 123

FUNCTIONAL REQUIREMENT(S):

To provide environmental and physical protection to the Tug during transport protection to the Tug during transport and storage in the horizontal position.

EQUIPMENT DESCRIPTION:

A rubber impregnated nylon fabric cover fabricated to V shape in three segments which are assembled on the Tug by laced and zippered closures.

COST PER UNIT: $ 3500 (DESIGN AND DEVELOPMENT)

$ 800 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

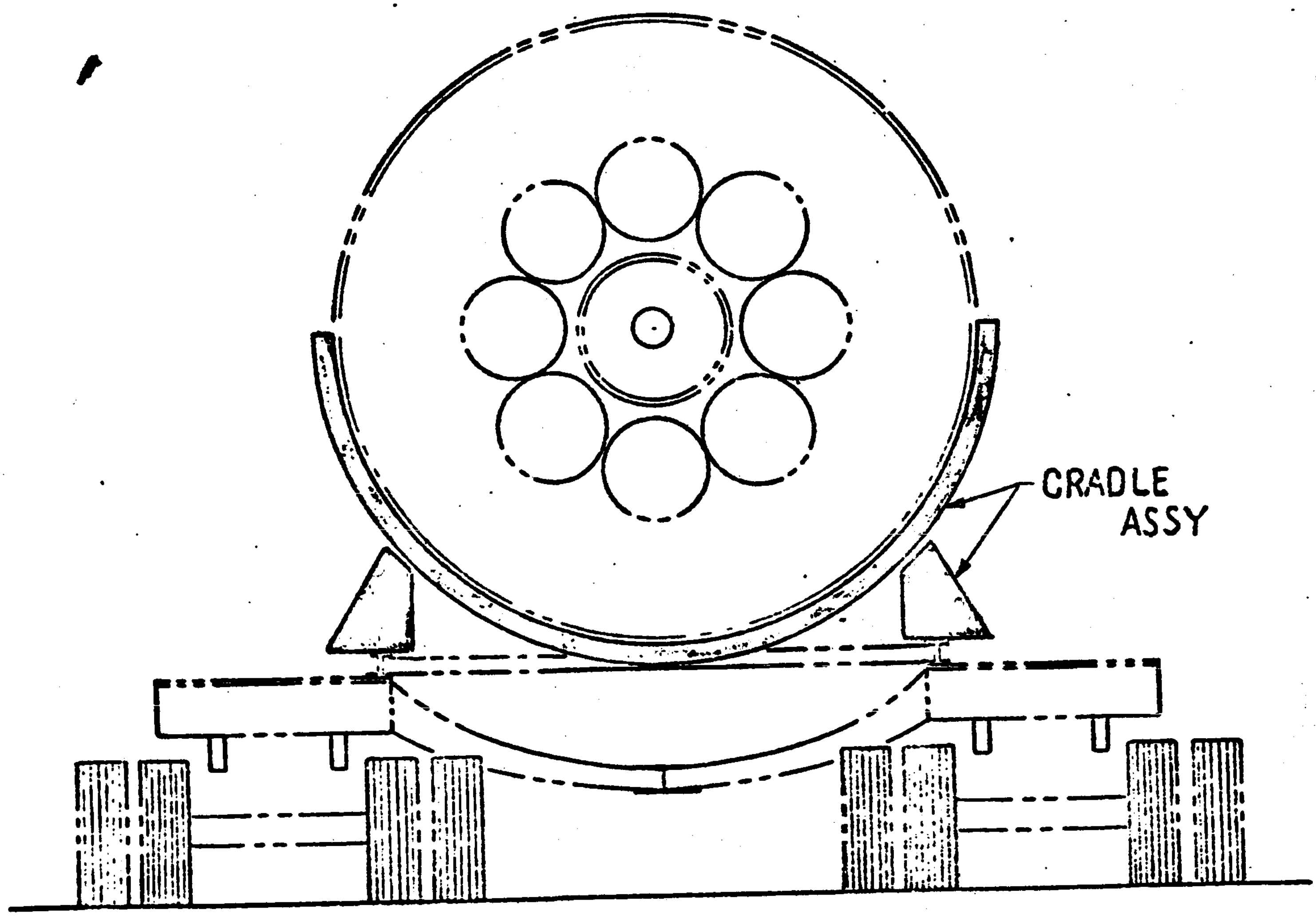
NEW X MODIFIED ____ AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE 0

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.2.1	KSC	4
1.1.22	WTR	1
1.1.24		

TOTAL REQUIRED 5 TOTAL COST $ 7,500



CRADLE ASSY

GSE DESCRIPTION SHEET

NAME: CRADLES EQUIPMENT NO. 124

FUNCTIONAL REQUIREMENT(S):

To provide a means to support and restrain the Tug on its transporter.

EQUIPMENT DESCRIPTION:

An intermediate steel structure to fit between and attach to the Tug and transporter.

COST PER UNIT: $ 100,000 (DESIGN AND DEVELOPMENT)

$ 65,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

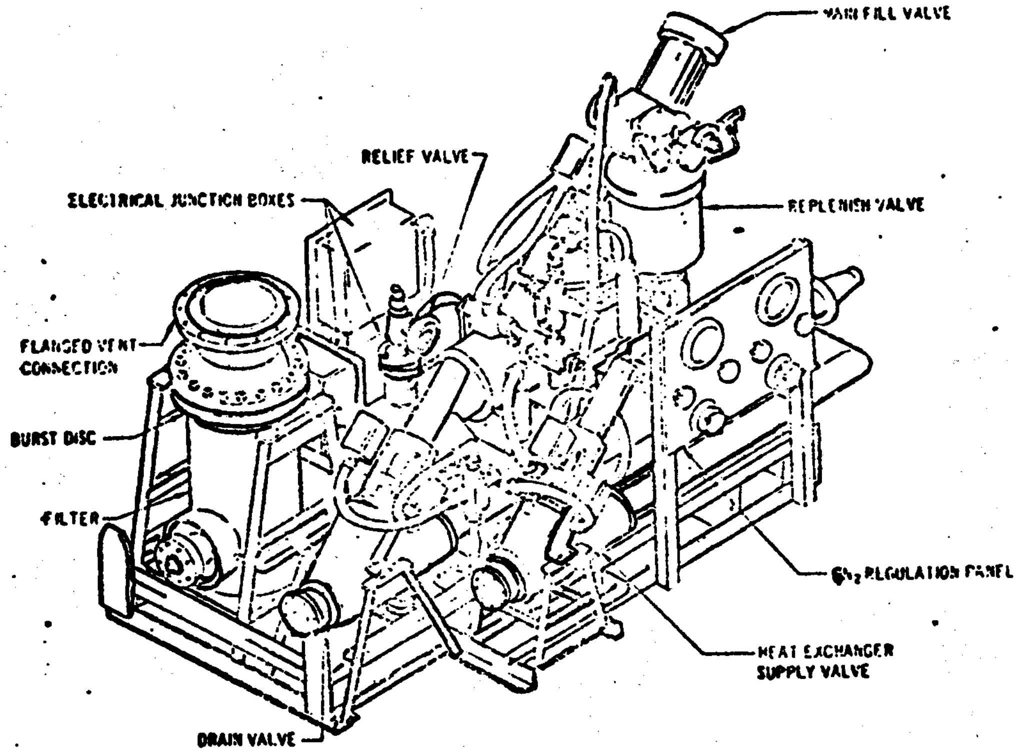
NEW X MODIFIED ____ AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE 0

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.20	KSC	4
	WTR	1
	Factory	1

TOTAL REQUIRED 5 TOTAL COST $ 425,000



CRYOGENIC PROPELLANT LOADING COMPLEX

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: CRYO. PROPELLANT LOADING COMPLEX **EQUIPMENT NO.** 125

FUNCTIONAL REQUIREMENT(S):

Provide for transfer and control of LO_2 and LH_2 from facility to vehicle umbilical.

EQUIPMENT DESCRIPTION:

LH_2 and LO_2 loading complex utilizing hardware from Sacramento Test Center and KSC where possible. (Control valves, umbilicals, etc.) (Utilize Shuttle topping system.) Same as DSV-4B-331 and -332.

COST $ 40,000 (DESIGN AND DEVELOPMENT)

$ 20,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW ________ MODIFIED X AS IS X GFE facilities at ETR

1ST YEAR REQ'D ________ NUMBER AVAILABLE ________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.4.3	KSC	2
	WTR	1

TOTAL REQUIRED 3 TOTAL COST $ 100,000

E-46

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: CRYO. TANK TRUCKS EQUIPMENT NO. 126

FUNCTIONAL REQUIREMENT(S):

Removal of residual cryogenic propellants during post launch safing.

EQUIPMENT DESCRIPTION:

Cryogenic tanker trucks. GFE at facility.

COST $ ______ (DESIGN AND DEVELOPMENT)

$ ______ (RECURRING/UNIT)

EQUIPMENT CATEGORY:

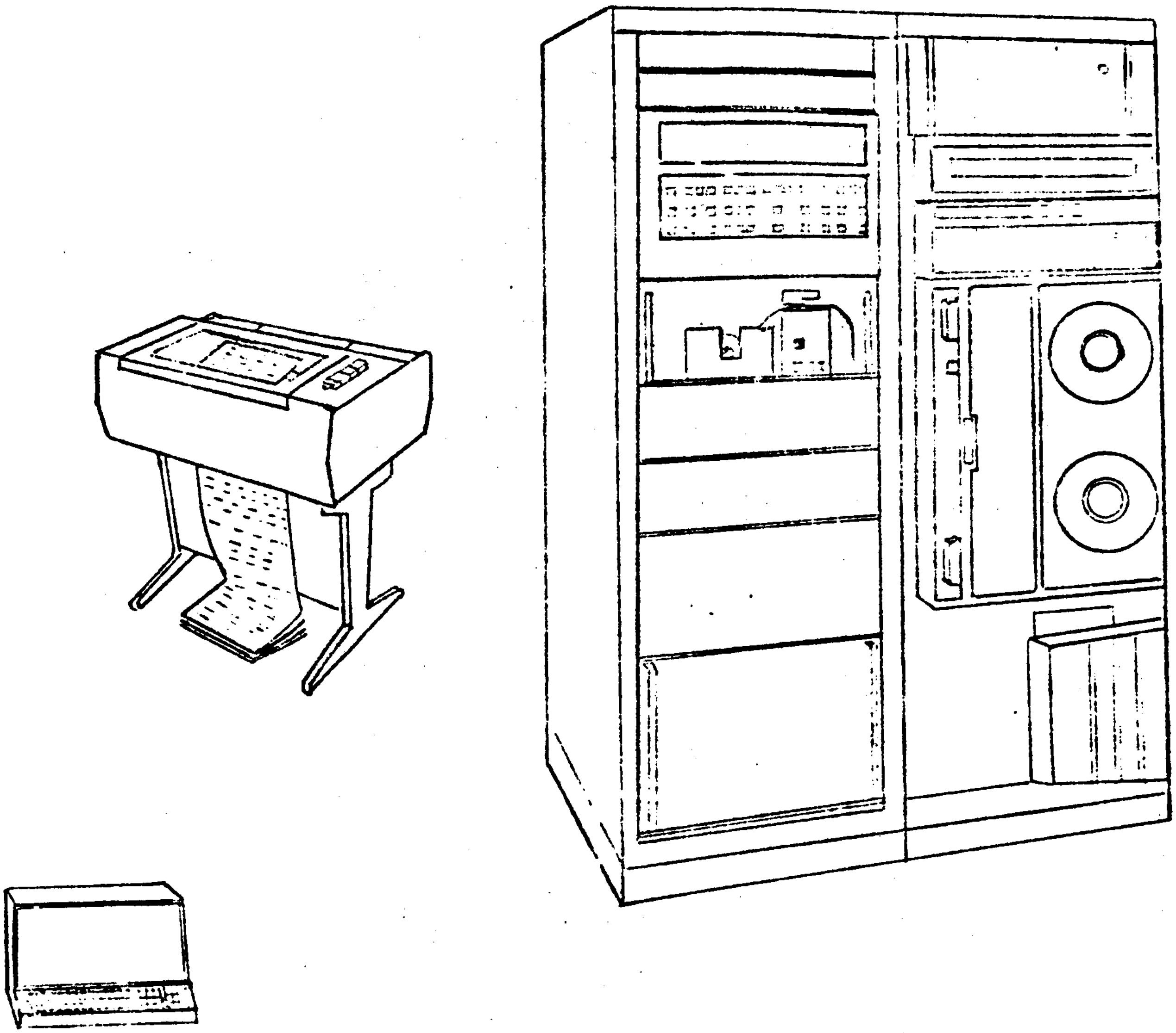
NEW ______ MODIFIED ______ AS IS X

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
3.1.1	KSC	1
	WTR	1

TOTAL REQUIRED 2 TOTAL COST $ -0-



DATA MANAGEMENT TEST SET

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: DATA MANAGEMENT SYSTEM T/S (DMST/S) EQUIPMENT NO. 127

FUNCTIONAL REQUIREMENT(S):

Controls operation of DMS computer and monitors computer status, initials program loading and verification, performs functional verification of DMS command and control functions, interface with other T/S for dedicated displays, verify selected subsystem parameters as program.

EQUIPMENT DESCRIPTION:

Portable console interfacing with computer for program verification and DMS memory dump C/O, paper tape memory loader, tape reader, DMS computer control and status panel, dedicated display panel for DMS function and programmable display for other subsystem functions (GNC, Comm, Power, and Prop.) - CRT

COST PER UNIT: $ 1,033,000 (NON-RECURRING)

$ 412,000 (RECURRING/YEAR)

EQUIPMENT CATEGORY:

NEW X MODIFIED ________ AS IS ________

1ST YEAR REQ'D ________ NUMBER AVAILABLE ________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.5, 1.1.7 ALL	TPF/KSC	1
1.1.8 ALL, 1.1.9 ALL	MCF/KSC	1
2.3.9, 2.4.3	Launch Pad/KSC	2
	PPF/WTR	1
	MCF/WTR	1
	Factory	1

TOTAL REQUIRED 7 TOTAL COST $ 3,917,000

GSE DESCRIPTION SHEET

NAME: TELEMETRY GROUND STATION EQUIPMENT NO. 128

FUNCTIONAL REQUIREMENT(S):

Receives and demodulates PCM data from Tug down link either open or closed loop. Provides for output to computer storage or conversion of data to external display units.

EQUIPMENT DESCRIPTION:

See attachment.

COST PER UNIT: $ -0- (NON-RECURRING)

$ -0- (RECURRING/YEAR)

EQUIPMENT CATEGORY:

NEW ____ MODIFIED ____ AS IS X

1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

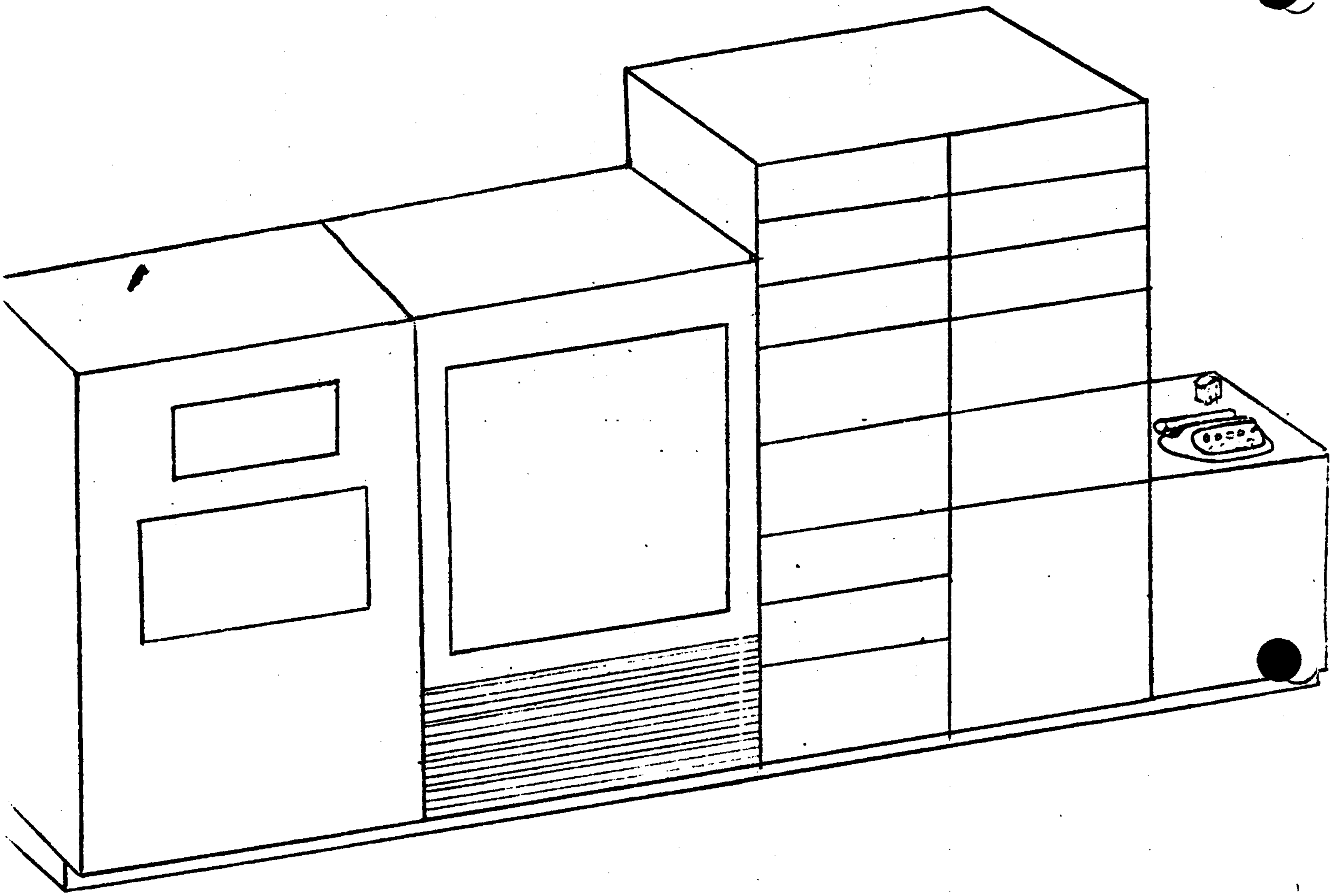
EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.3.9	KSC (remote from launch pad)	1
2.4.3	WTR (remote from launch pad)	1

TOTAL REQUIRED 2 TOTAL COST $ -0-

The Western Test Range has a 30 foot Unified S-Band (USB) remote tracking site which is part of the spaceflight Tracking and Data Network (STDN). The "unified" concept of the USB system provides multiple functions -- command, telemetry, tracking and two-way voice communications -- to be accomplished simultaneously between 2090 and 2120 MHz and a downlink frequency between 2200 and 2300 MHz.

The Eastern Test Range has a dual AFSCF remote tracking station (RTS) located at Vandenberg California capable of operating with two satellites simultaneously. The RTS contains S-band equipment designated as a Space Ground Link Subsystem (SGLS) installation. The SGLS equipment is standardized and interfaces with two antennas, one is a 60 foot antenna while the other is a 46 foot dish. The SGLS contains receiving and transmitting equipment necessary for data reception and commanding of space vehicles.



DIGITAL EVENTS RECORDER (DER)

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: DIGITAL EVENTS RECORDER EQUIPMENT NO. 129

FUNCTIONAL REQUIREMENT(S):

Collects discrete status (on/off) data and compares data against previously recorded information. Prints or tape punches output results for permanent record.

EQUIPMENT DESCRIPTION:

Similar to DSV-4B-289

COST PER UNIT: $ 200,000 (NON-RECURRING)

$ 182,000 (RECURRING/YEAR)

EQUIPMENT CATEGORY:

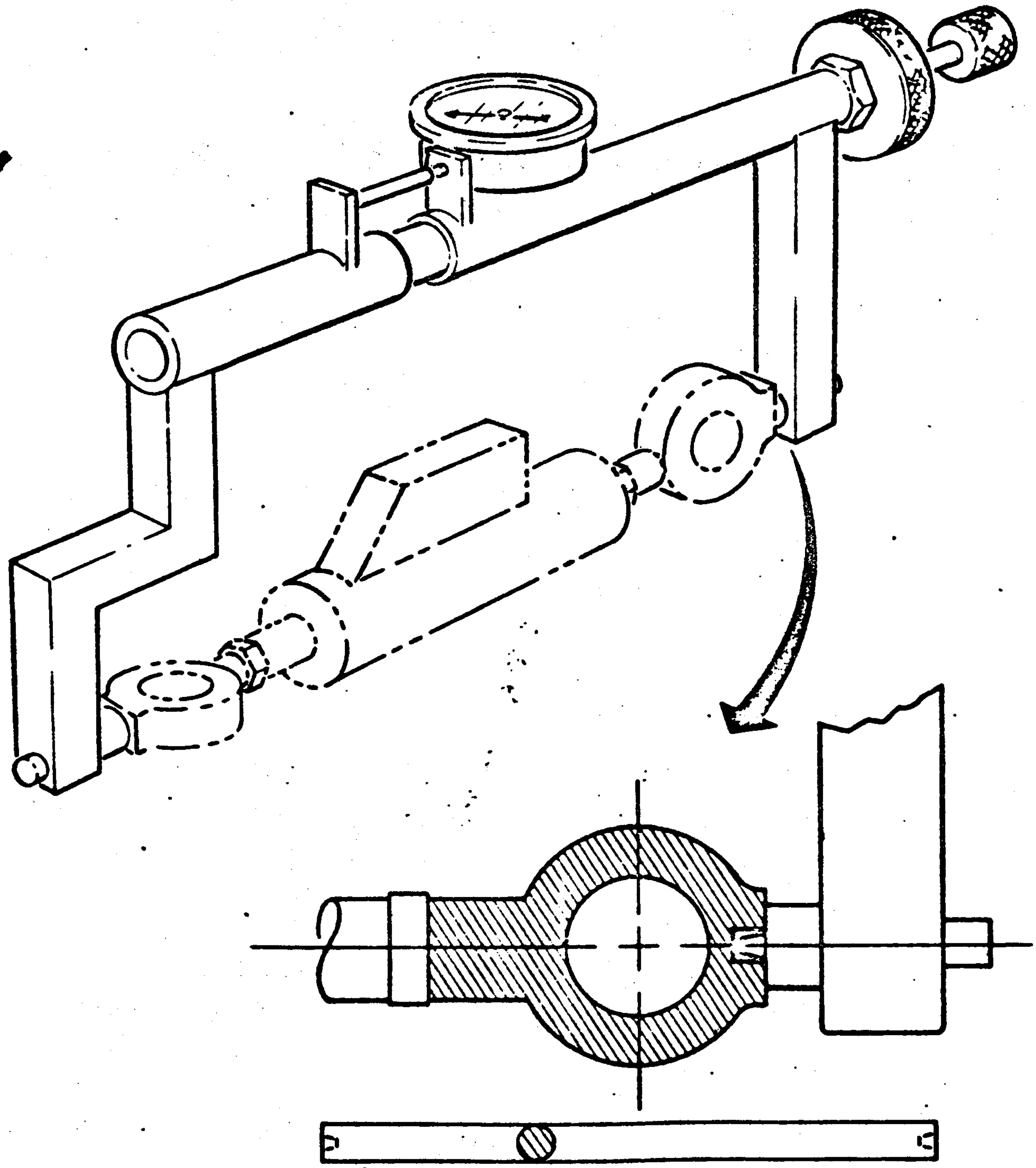
NEW ________ MODIFIED ________ AS IS ________

1ST YEAR REQ'D ________ NUMBER AVAILABLE ________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.4.3	KSC (TPF)	1 GFE
	WTR (PPF)	1
	Factory	1 GFE

TOTAL REQUIRED 2 TOTAL COST $ 382,000



Engine Actuator Adjustment Kit

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: ENGINE ACTUATOR FIXTURE EQUIPMENT NO. 130

FUNCTIONAL REQUIREMENT(S):

Checkout electrical/mechanical actuators on Tug.

EQUIPMENT DESCRIPTION:

COST PER UNIT: $ 10,000 (NON-RECURRING)

$ 4,000 (RECURRING/YEAR)

EQUIPMENT CATEGORY:

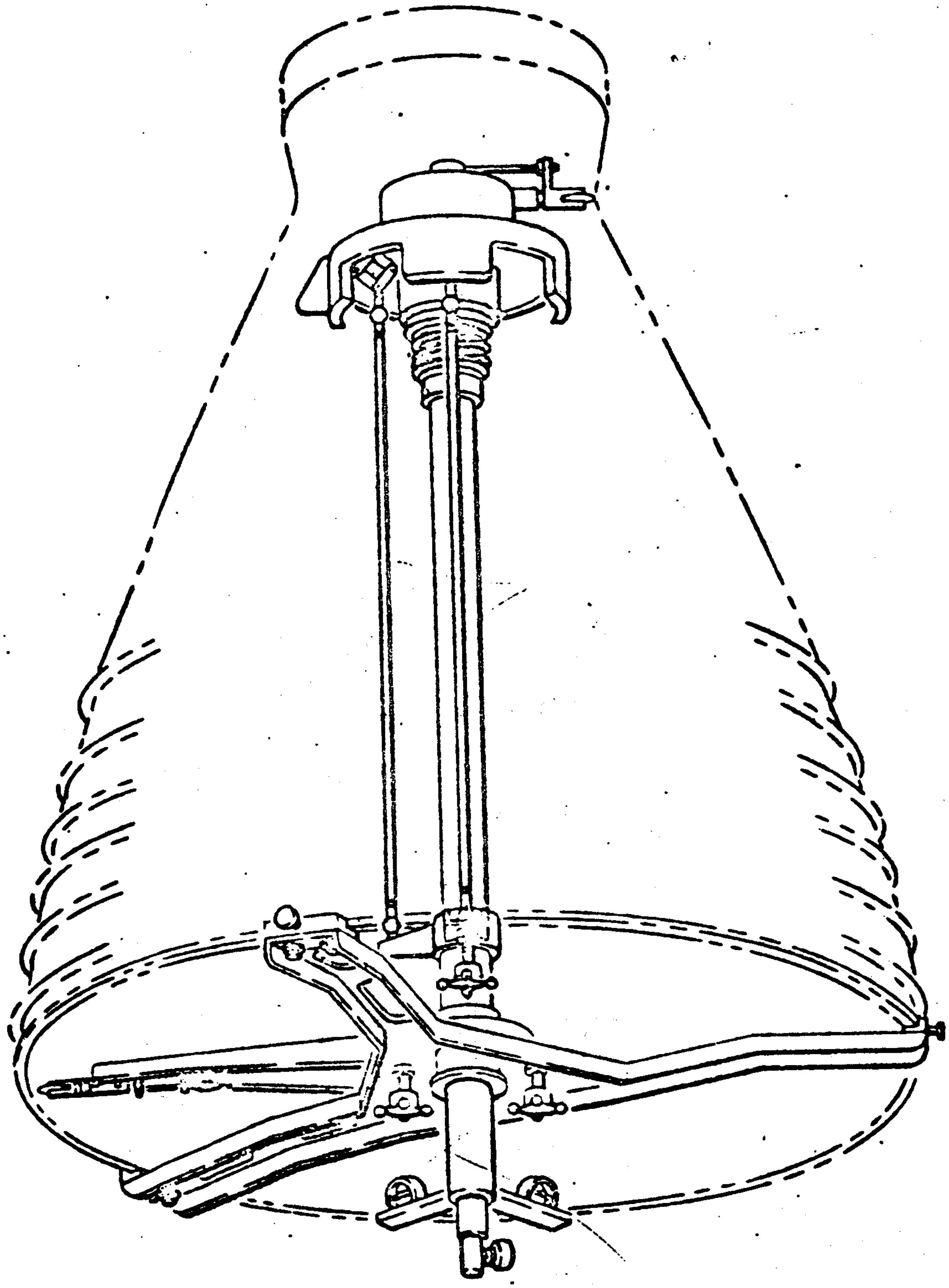
NEW ______ MODIFIED ______ AS IS ______

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.9.2	TPF/KSC	1
	PPF/WTR	1
	Factory	1

TOTAL REQUIRED 3 TOTAL COST $ 22,000



Engine Alignment Kit

E-56

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: ENGINE ALIGNMENT KIT EQUIPMENT NO. 131

FUNCTIONAL REQUIREMENT(S):

Establishes centerline of engine with respect to stage centerline.

EQUIPMENT DESCRIPTION:

Similar to DSV-4B-324

COST $ 25,000 (DESIGN AND DEVELOPMENT)

$ 15,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW X MODIFIED 15% AS IS 85%

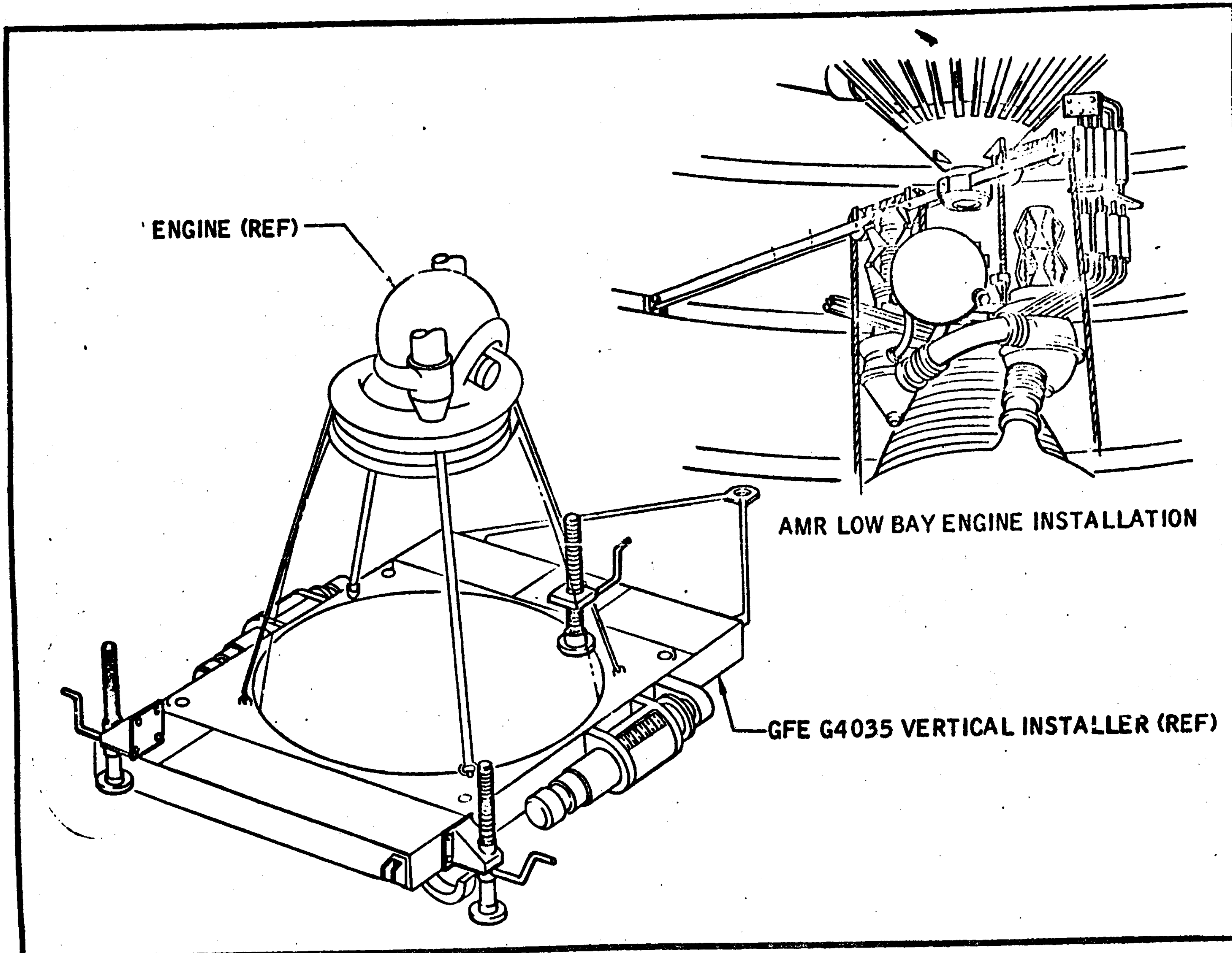
1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.9.2	TPF/KSC	1
	PPF/WTR	1

TOTAL REQUIRED 2 TOTAL COST $ 55,000

E-57



Engine Handling Kit

E-58

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: ENGINE HANDLING KIT EQUIPMENT NO. 132

FUNCTIONAL REQUIREMENT(S):

Provides hardware required for handling engine during removal from and installation onto stage.

EQUIPMENT DESCRIPTION:

Handling plug, grame, and shipping container. (GFE furnished with engine.)

COST $ -0- (DESIGN AND DEVELOPMENT)

$ -0- (RECURRING/UNIT)

EQUIPMENT CATEGORY:

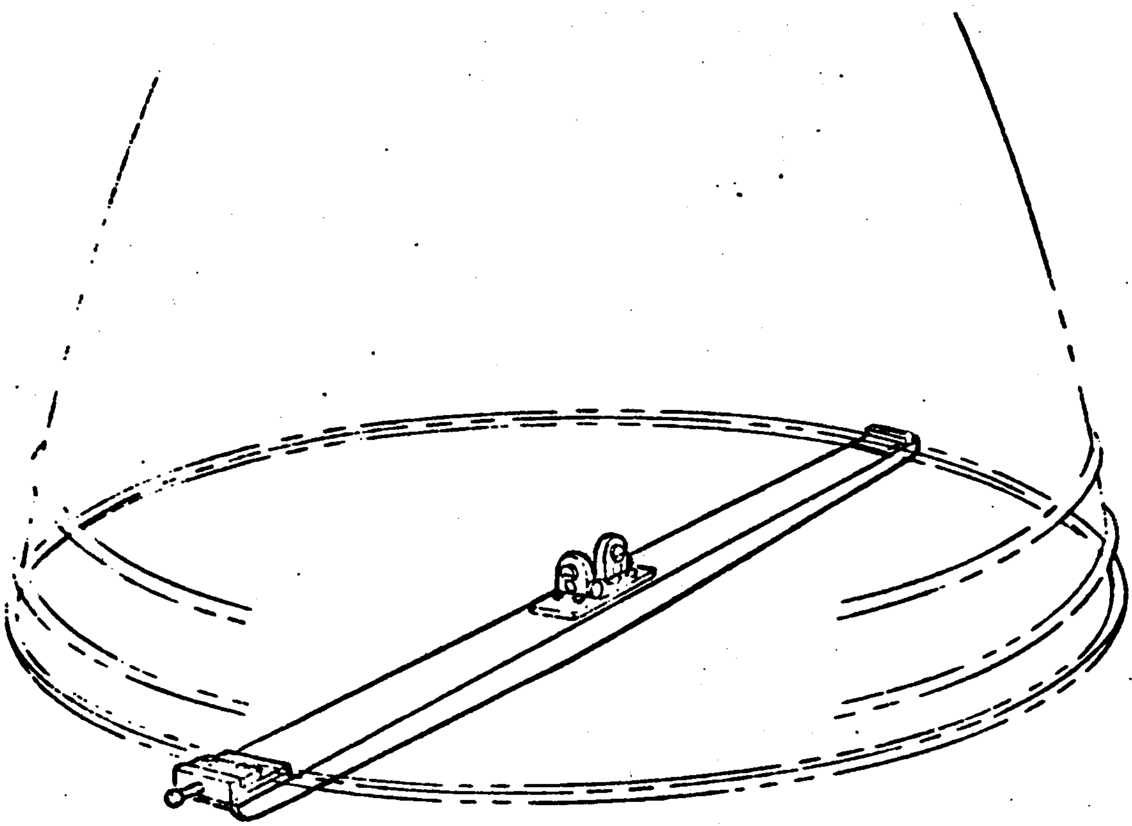
NEW ______ MODIFIED ______ AS IS X GFE with engine

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
	TPF/KSC	1
	PPF/WTR	1
	Factory	1

TOTAL REQUIRED 3 TOTAL COST $ -0-



Calibration Fixture, Engine Position

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: ENGINE POSITION CALIBRATION FIXTURE EQUIPMENT NO. 133

FUNCTIONAL REQUIREMENT(S):

Measures engine geometric vector with respect to theorectical stage centerline for various positions of the engine.

EQUIPMENT DESCRIPTION:

Similar to DSV-4B-629 and DSV-4B-699

COST $ 4,000 (DESIGN AND DEVELOPMENT)

$ 2,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW X MODIFIED ______ AS IS ______

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.9.2	TPF/KSC	1
	PPF/WTR	1
	Factory	1

TOTAL REQUIRED 2 TOTAL COST $ 8,000

E-61

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: EQUIPMENT VAN EQUIPMENT NO. 134

FUNCTIONAL REQUIREMENT(S):

To provide for miscellaneous transport

EQUIPMENT DESCRIPTION:

1-1/2 ton two axle van (Bob Tail) truck. GFE available at facility.

COST $______ (DESIGN AND DEVELOPMENT)

$______ (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED ______ AS IS X GFE

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.22	KSC	3
1.1.25	WTR	2

TOTAL REQUIRED 5 TOTAL COST $ -0-

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: GAS SAMPLING EQUIPMENT EQUIPMENT NO. 139

FUNCTIONAL REQUIREMENT(S):

Verify acceptable moisture content of propellant systems prior to loading.

Verify safe levels of hazardous gas concentrations.

EQUIPMENT DESCRIPTION:

Moisture monitor, hazardous gas detectors and analyzers.

COST $ 0 (DESIGN AND DEVELOPMENT)

$ 150 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

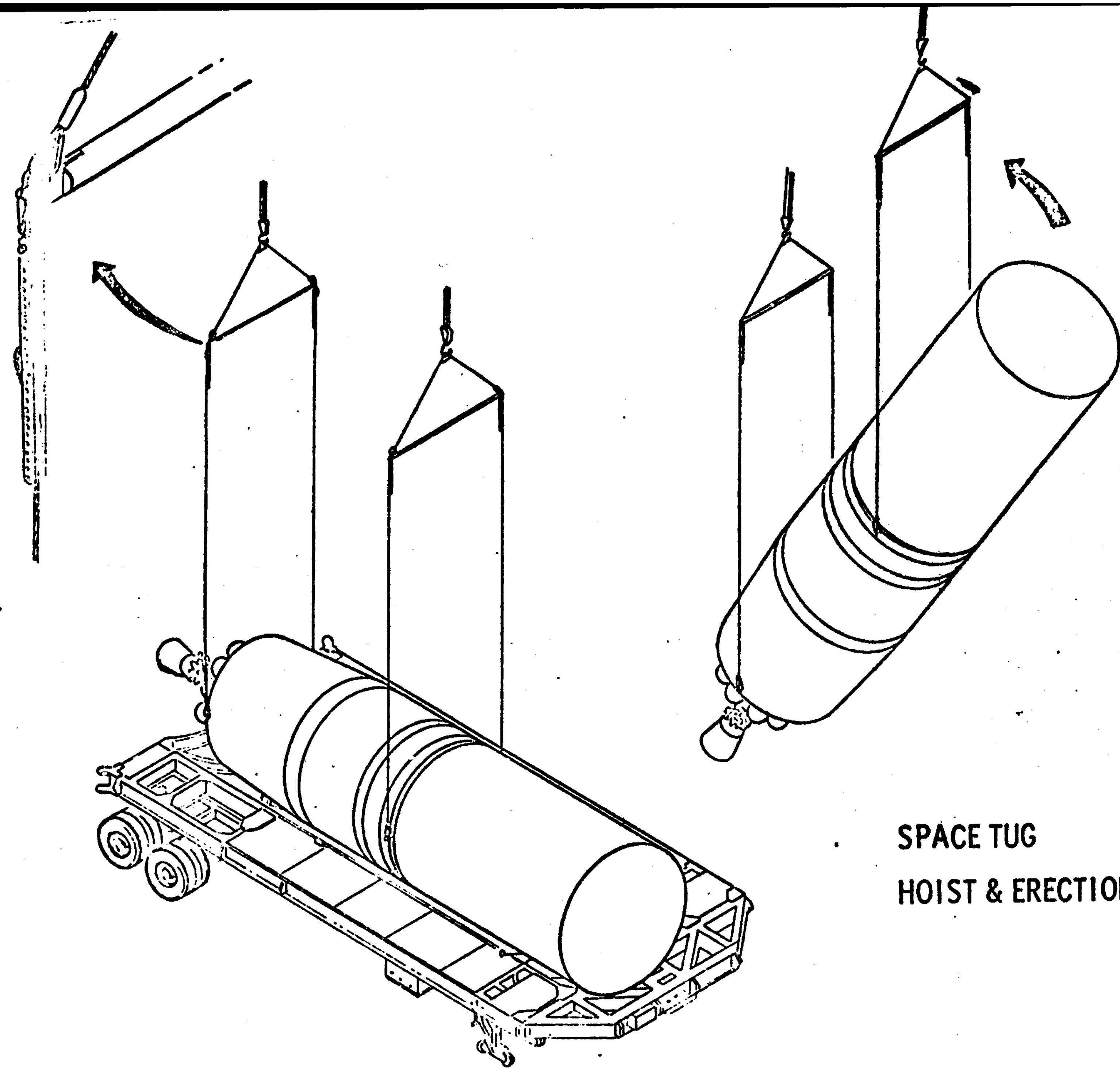
NEW ______ MODIFIED ______ AS IS X

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
3.1.1	Safing Area/KSC	1
	Storable Prop/KSC	1
	Portable/KSC	1
	Safing Area/WTR	1
	Storable Prop/WTR	1
	Portable/WTR	1

TOTAL REQUIRED 6 TOTAL COST $ 900



SPACE TUG

HOIST & ERECTION KIT

CONFIGURATION OPTION A11

GSE DESCRIPTION SHEET

NAME: HANDLING EQUIPMENT EQUIPMENT NO. 140

FUNCTIONAL REQUIREMENT(S):

Provide means to hoist and/or rotate Tug from either a horizontal or vertical attitude with either one or two cranes as required.

EQUIPMENT DESCRIPTION:

Two wire sling and spreader bar assemblies with appropriate shackle fittings. One assembly to be adjustable in length.

COST $ 25,000 (DESIGN AND DEVELOPMENT)

$ 5,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

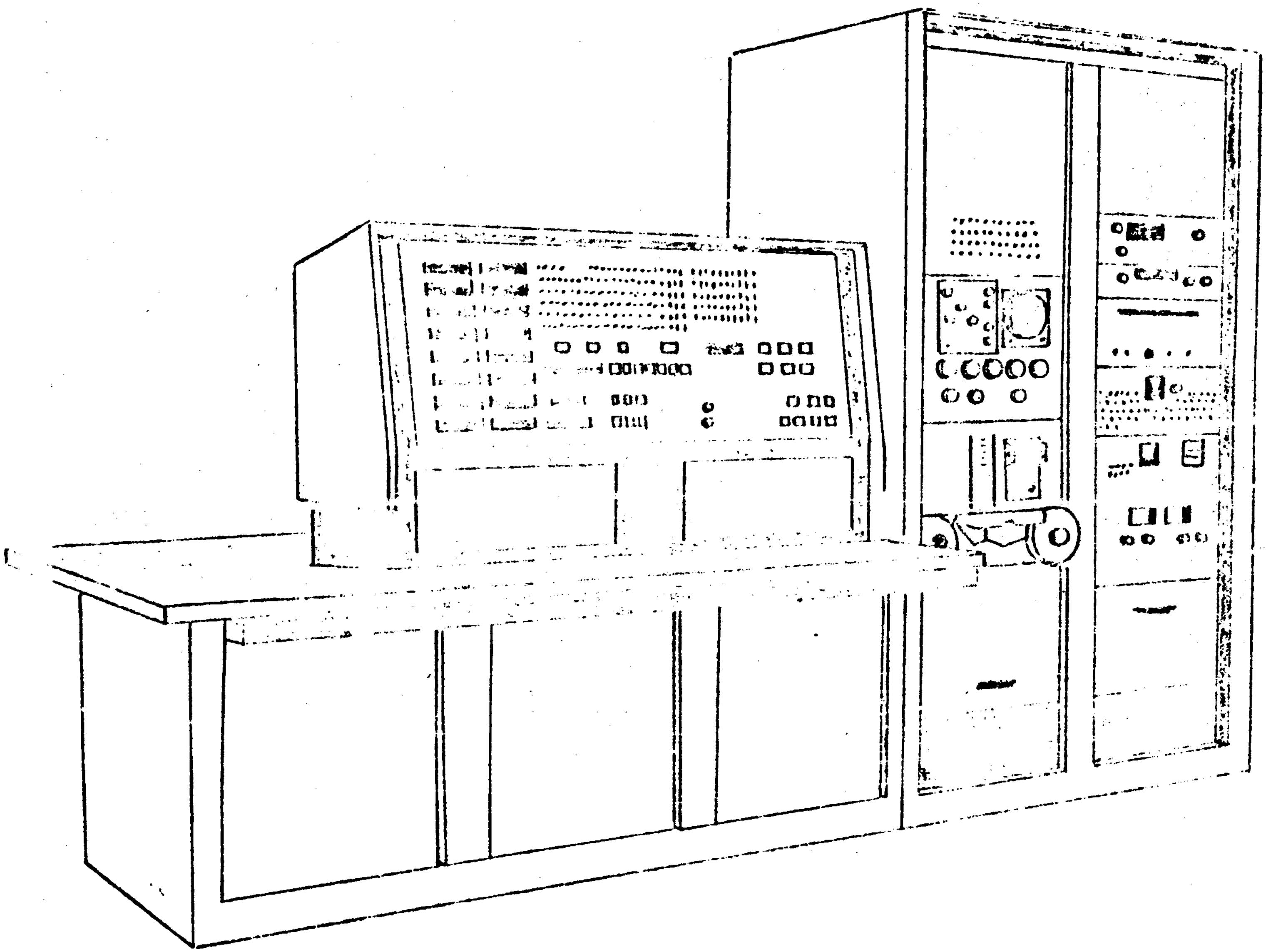
NEW X MODIFIED ____ AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE 0

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.1.3	Pad/KSC	2
2.2.1.2	MCF/KSC	1
2.2.3	TPF/KSC	1
2.3.6	Pad/WTR	2
2.4.5, 2.4.8	MCF/WTR	1
	PPF/WTR	1

TOTAL REQUIRED 8 TOTAL COST $ 65,000



GUIDANCE AND NAVIGATION TEST SET

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: GUIDANCE AND NAVIGATION TEST SET EQUIPMENT NO. 142

FUNCTIONAL REQUIREMENT(S):

Monitors and verifies checkout of IMU and GC. It provides calibration, alignment and simulation of navigation programs. Capable of simulations of all flight programs.

EQUIPMENT DESCRIPTION:

Rate table and associated electronic bays which include display panel, control panel, oscilloscope, universal counter, digital voltmeter, interface (DIU) assy, power supplies, digital printer paper tape punch, test point control panel, down-link display panel, etc. (Available from Delta Program.)

COST PER UNIT: $ -0- (NON-RECURRING)

$ -0- (RECURRING/YEAR)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED ______ AS IS X GFE

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.13	KSC	1
	WTR	1
	Factory	1

TOTAL REQUIRED 3 TOTAL COST $ -0-

CONFIGURATION OPTION ____________

GSE DESCRIPTION SHEET

NAME: GUIDANCE AND NAVIGATION SYSTEM CHECKOUT KIT EQUIPMENT NO. 143

FUNCTIONAL REQUIREMENT(S):

Interfaces between Tug IMU and GC and the laboratory test equipment. Also provides mounting of IMU to rate table.

EQUIPMENT DESCRIPTION:

Consists of IMU holding fixture and cables.

(Available from Delta Program.)

COST PER UNIT: $ -0- (NON-RECURRING)

$ -0- (RECURRING/YEAR)

EQUIPMENT CATEGORY:

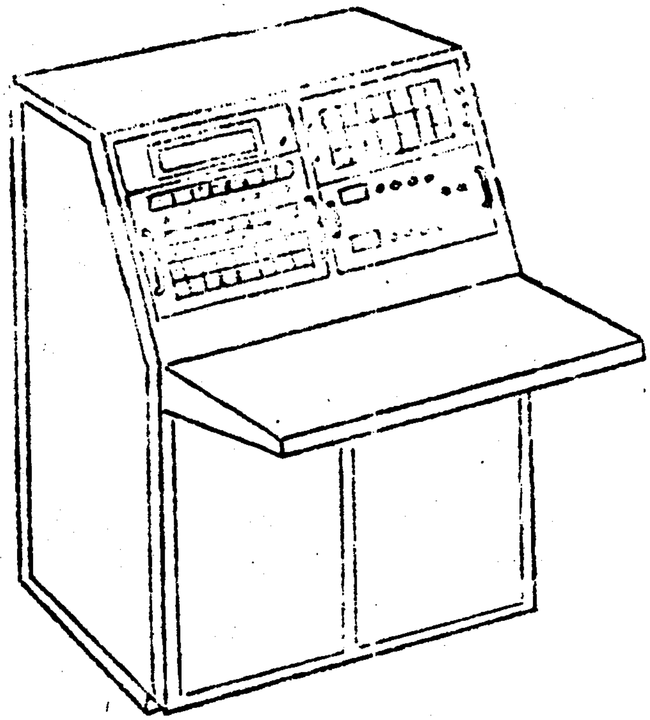
NEW ____________ MODIFIED ____________ AS IS X GFE

1ST YEAR REQ'D ____________ NUMBER AVAILABLE ____________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.13	KSC	1
	WTR	1
	Factory	1

TOTAL REQUIRED 3 TOTAL COST $ -0-



LAUNCH COUNTDOWN CONSOLE

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: LAUNCH COUNT DOWN CONSOLE EQUIPMENT NO. 145

FUNCTIONAL REQUIREMENT(S):

Controls and monitors launch checkout and count down of Tug vehicle.

EQUIPMENT DESCRIPTION:

Console with intercom and count down clock, status indicators, alpha mumerical display and associated circuitry.

COST $ 30,000 (DESIGN AND DEVELOPMENT)

$ 20,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW X MODIFIED ________ AS IS X GFE at ETR

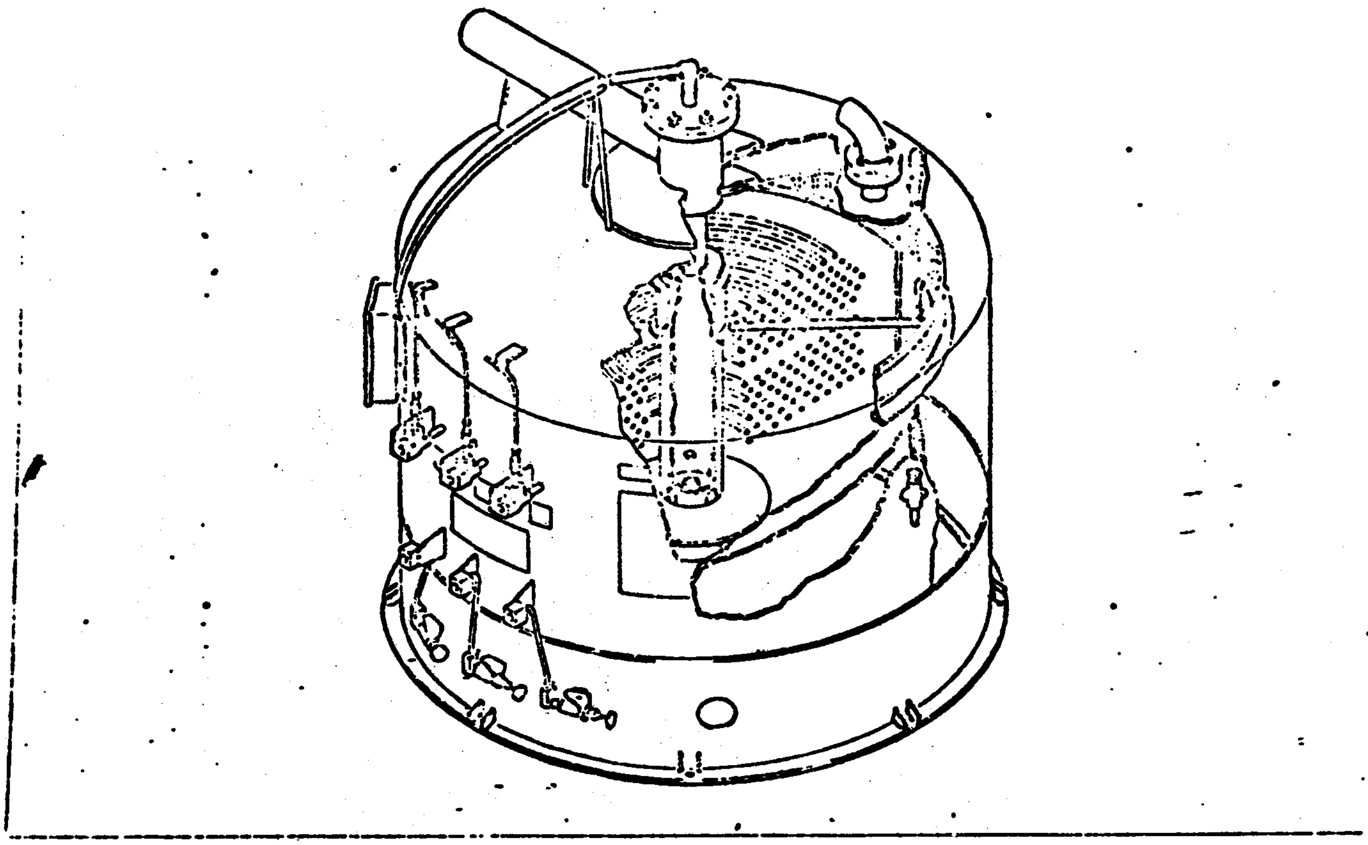
1ST YEAR REQ'D ________ NUMBER AVAILABLE ________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.4.3	KSC	2
2.4.4	WTR	1

TOTAL REQUIRED 3 TOTAL COST $ 50,000

E-70



LH_2 - HEAT EXCHANGER

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: LH_2-He HEAT EXCHANGER **EQUIPMENT NO.** 147

FUNCTIONAL REQUIREMENT(S):

Provide prechilling of helium used for APS tank pressurization or main propellant tank pressurization

EQUIPMENT DESCRIPTION:

LH_2-He heat exchanger utilizing hardware from Sacramento Test Center and KSC where possible.

COST $ 0 (DESIGN AND DEVELOPMENT)

$ 20,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

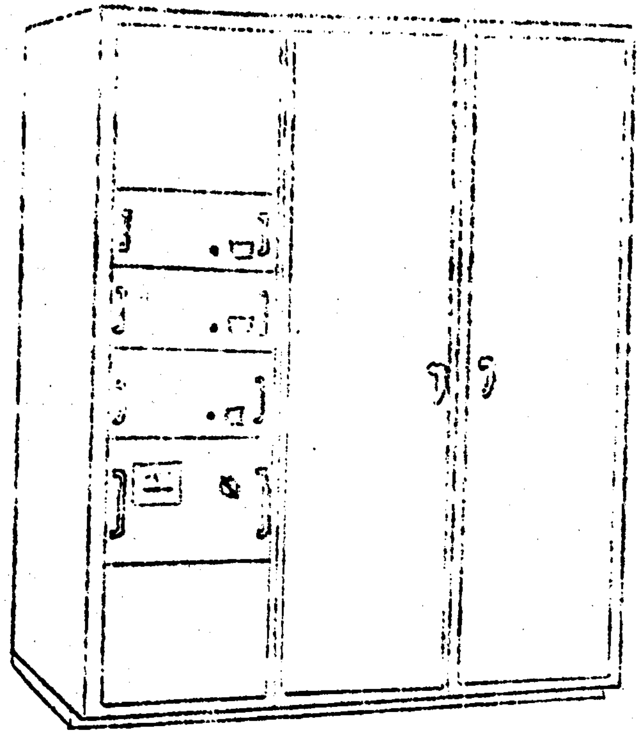
NEW ______ MODIFIED X AS IS ______

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.8.2	KSC	2
1.1.9.7	WTR	1

TOTAL REQUIRED 3 TOTAL COST $ 60,000



SIGNAL CONDITIONING UNIT

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: SIGNAL CONDITIONING UNIT EQUIPMENT NO. 148

FUNCTIONAL REQUIREMENT(S):

Interfaces between Tug vehicle and GSE for signal and power conditioning, and distribution

EQUIPMENT DESCRIPTION:

Consists of a 3 bay console which contains junction box, (1) 1032 point patch panel assembly, (10) isolation amplifiers, (1) 4 row relay-plane, (10) buffer amplifiers, (1) logic power supply, and (20) connectors and associated wiring. (Similar to DSV-4B-133).

COST $ 300,000 (DESIGN AND DEVELOPMENT)

$ 120,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW x MODIFIED ________ AS IS ________

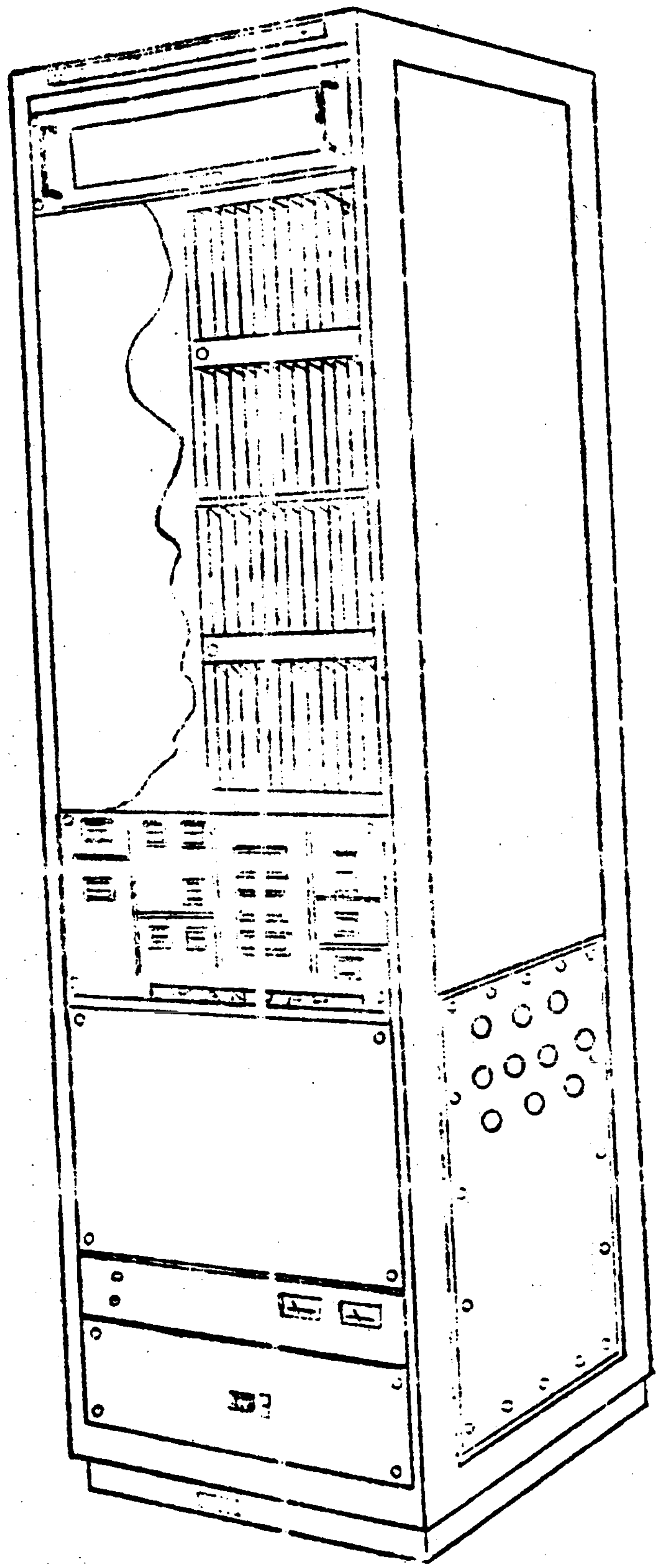
1ST YEAR REQ'D ________ NUMBER AVAILABLE ________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.5	TPF/KSC	1
1.1.7 ALL	MCF/KSC	1
1.1.8 ALL	PPF/WTR	1
2.3.9	MCF/WTR	1
2.4.3	Launch Pad/KSC	2
	Factory	1

TOTAL REQUIRED 7 TOTAL COST $ 1,140,000

E-74



ORBITER SIMULATOR

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: ORBITER SIMULATOR EQUIPMENT NO. 149

FUNCTIONAL REQUIREMENT(S):

Functionally simulates orbiter/Tug interfaces for verification of electrical parameters

EQUIPMENT DESCRIPTION:

Portable test set containing encoder, decoder and load test circuits. Contains switches and indicator lights

COST $ 400,000 (DESIGN AND DEVELOPMENT)

$ 100,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

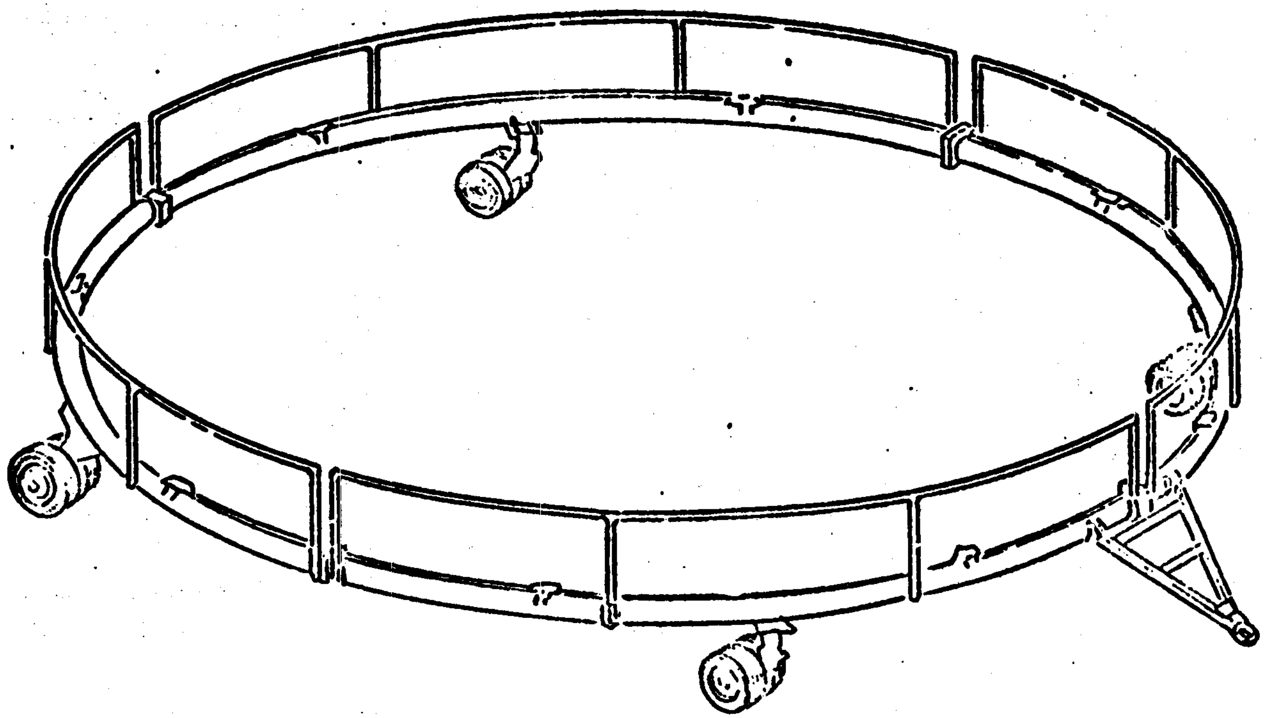
NEW ______ MODIFIED ______ AS IS ______

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.7.9	TPF/KSC	1
1.1.8.9	PPF/WTR	1
1.1.9.9	Factory	1

TOTAL REQUIRED 2 TOTAL COST $ 700,000



PAYLOAD ADAPTER HANDLING KIT

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: PAYLOAD ADAPTER HANDLING KIT EQUIPMENT NO. 150

FUNCTIONAL REQUIREMENT(S):

Provides protection and means of handling payload interface unit.

EQUIPMENT DESCRIPTION:

Similar to DSV-4B-352

COST $ 10,000 (DESIGN AND DEVELOPMENT)

$ 5,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW x MODIFIED ________ AS IS ________

1ST YEAR REQ'D ________ NUMBER AVAILABLE ________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.2.3	TPF/KSC	1
	PPF/KSC	1
	PPF/WTR	1

TOTAL REQUIRED 3 TOTAL COST $ 25,000

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: PERSONNEL PROTECTION EQUIPMENT EQUIPMENT NO. 152

FUNCTIONAL REQUIREMENT(S):

Provide environmental protection for storable APS loading crew.

EQUIPMENT DESCRIPTION:

Protective clothing, breathing devices, and fire equipment. SCAPE suits, if required.

COST $ 0 (DESIGN AND DEVELOPMENT)

$ 4000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED ______ AS IS X

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.1.7	KSC	4
	WTR	4

TOTAL REQUIRED 8 TOTAL COST $ 32,000

E-79

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: PNEUMATIC CONSOLE ACPS PORTABLE TEST SET EQUIPMENT NO. 153

FUNCTIONAL REQUIREMENT(S):

Manually checks electrical continuity of solenoid valves talkback and actuation of solenoid valves, pressure switches, and transducers.

EQUIPMENT DESCRIPTION:

Similar to DSV-4B-286 and 286A

COST $ 76,000 (DESIGN AND DEVELOPMENT)

$ 28,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW x MODIFIED ________ AS IS ________

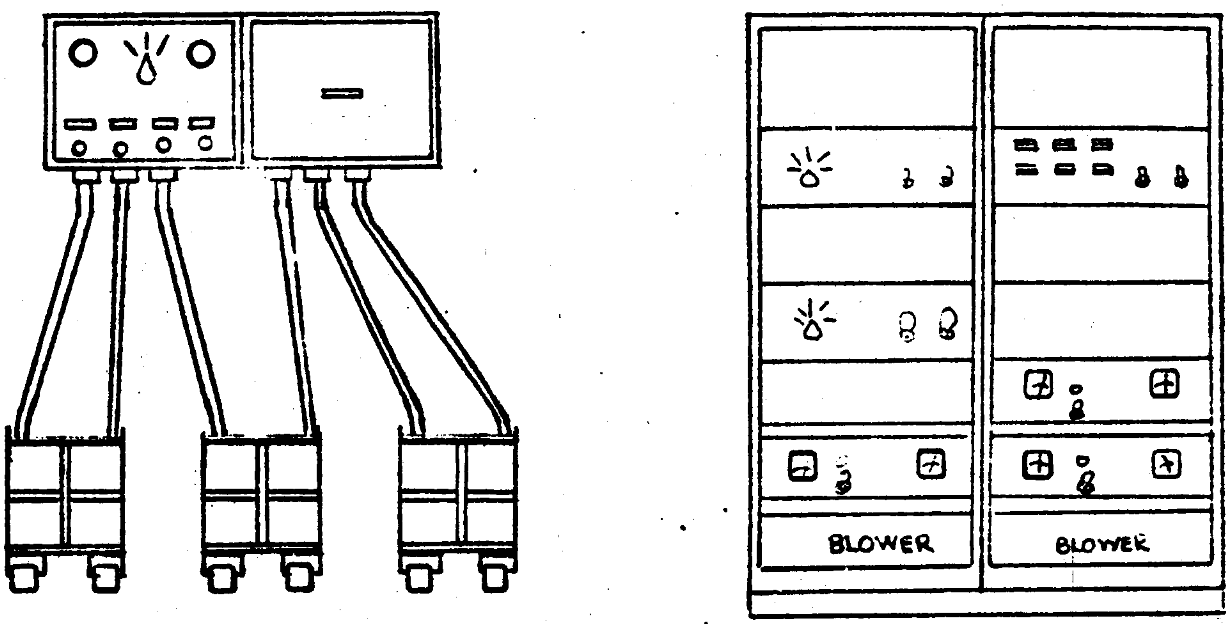
1ST YEAR REQ'D ________ NUMBER AVAILABLE ________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.1.7	KSC STORABLE	1
	WTR STORABLE	1
	FACTORY	1

TOTAL REQUIRED 3 TOTAL COST $ 160,000

E-80



POWER SYSTEM TEST SET

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: POWER SYSTEM T/S (PSTS) EQUIPMENT NO. 155

FUNCTIONAL REQUIREMENT(S):

Provide means to load fuel cells and vehicle power distribution system. Provide ground power sources for vehicle and GSE. Provide emergency power in event facility power malfunction.

EQUIPMENT DESCRIPTION:

Two bay rack of electrical equipment containing two independent programmable power supplies for vehicle power, one programmable power supply for GSE power, and programmable loads for vehicle power system C/O, a backup battery unit is provided for emergency power.

COST PER UNIT: $ 134,000 (NON-RECURRING)

$ 48,000 (RECURRING/YEAR)

EQUIPMENT CATEGORY:

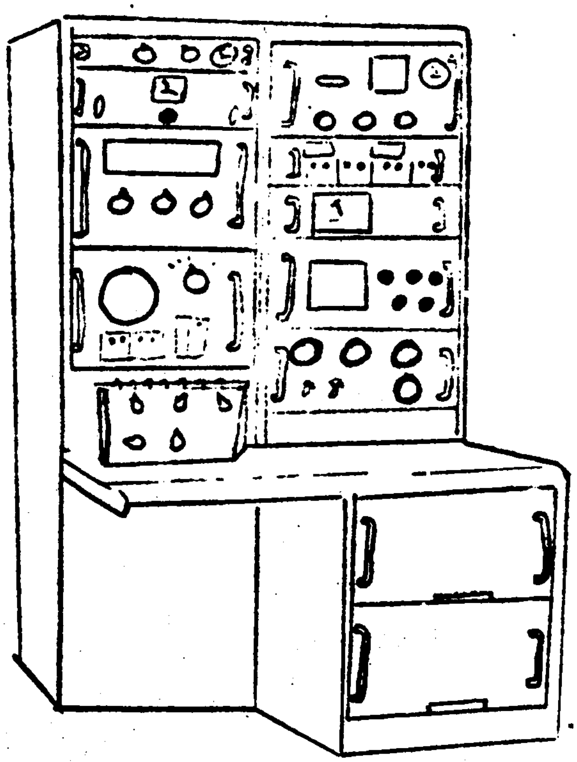
NEW X MODIFIED ________ AS IS ________

1ST YEAR REQ'D ________ NUMBER AVAILABLE ________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.5, 1.1.7 ALL	TPF/KSC	1
1.1.8 ALL 1.1.9 ALL	MCF/KSC	1
2.3.9, 2.4.2	PPF/WTR	1
2.4.3	MCF/WTR	1
	Launch Pad/ETR	2
	Factory	1

TOTAL REQUIRED 7 TOTAL COST $ 470,000



PRINTED CIRCUIT CARD COMPONENT TEST SET

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: PRINTED CIRCUIT CARD COMPONENT TEST SET EQUIPMENT NO. 157

FUNCTIONAL REQUIREMENT(S):

Tests printed circuit cards and isolates difficulties to component level. Provides voltages, input stimuli, and loads. Monitors outputs of cards being tested.

EQUIPMENT DESCRIPTION:

Similar to DSV-4B-104

COST $ 39,200 (DESIGN AND DEVELOPMENT)

$ 53,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

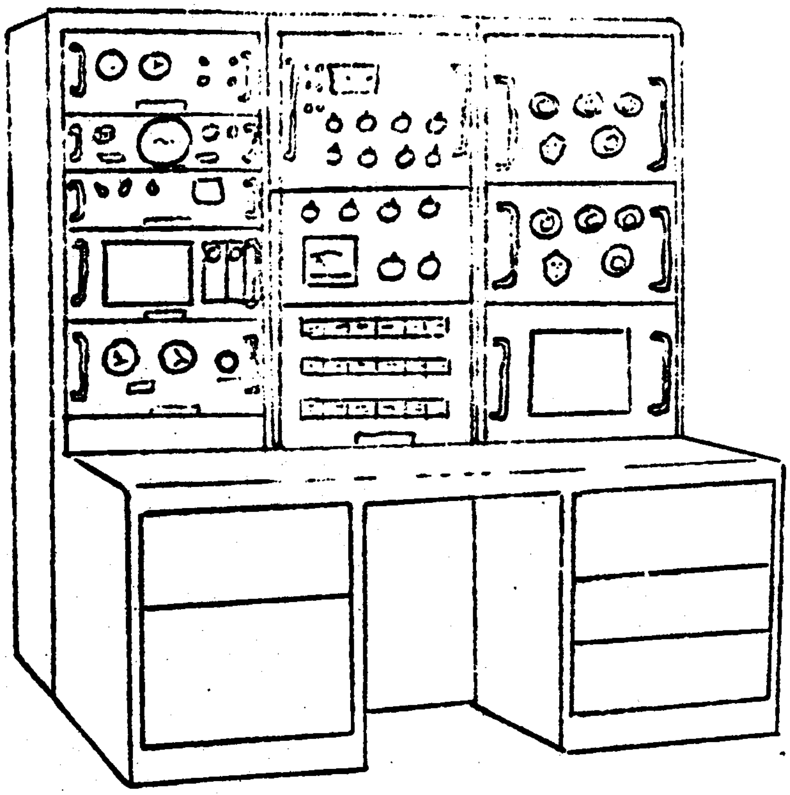
NEW ________ MODIFIED 20% AS IS 80%

1ST YEAR REQ'D ________ NUMBER AVAILABLE ________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
	Factory	1

TOTAL REQUIRED 1 TOTAL COST $ 92,000



PROPELLANT UTILIZATION COMPONENT TEST SET

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: PROPELLANT UTILIZATION COMPONENT TEST SET **EQUIPMENT NO.** 159

FUNCTIONAL REQUIREMENT(S):

Tests and calibrates P.U. electronics assembly adjustments.

EQUIPMENT DESCRIPTION:

Similar to DSV-4B-112

COST $ 127,600 (DESIGN AND DEVELOPMENT)

$ 56,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW X WTR MODIFIED 20% AS IS 80% ETR

1ST YEAR REQ'D ________ NUMBER AVAILABLE ________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.8.9	TPF/KSC	1
1.1.9.9	PPF/WTR	1
	Factory	1

TOTAL REQUIRED 3 **TOTAL COST** $ 295,600

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: PROPULSION COMPONENT REPAIR KIT EQUIPMENT NO. 160

FUNCTIONAL REQUIREMENT(S):

Provides equipment necessary for disassembly, repair, re-assembly, and test of propulsion components.

EQUIPMENT DESCRIPTION:

Collection of special tools, adapters, and other equipment.

COST $ 2,000 (DESIGN AND DEVELOPMENT)

$ 10,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

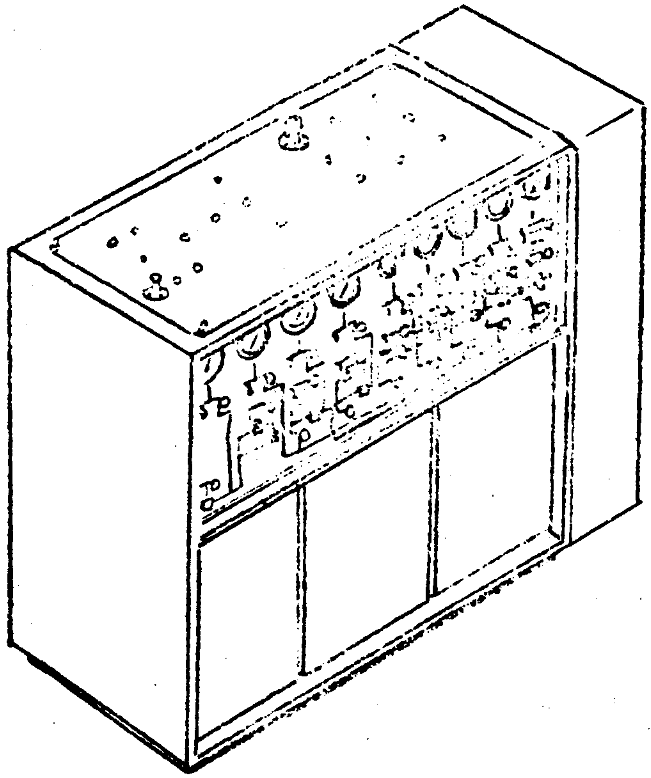
NEW x MODIFIED ______ AS IS ______

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.12	KSC	1
	WTR	1
	Factory	1

TOTAL REQUIRED 3 TOTAL COST $ 32,000



PROPULSION PNEUMATIC CONSOLE
(CHECKOUT)

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: PNEUMATIC SKID CHECKOUT EQUIPMENT NO. 161

FUNCTIONAL REQUIREMENT(S):

Provide regulated gas supplies to vehicle for pressurization of pneumatic and propellant systems. Used for leak and functional checks, purging, pressure draining, and application of blanket pressures.

EQUIPMENT DESCRIPTION:

Pneumatic console such as DSV-4B-321 modified as required for special Tug requirements.

COST PER UNIT: $ 50,000 (NON-RECURRING)

$ 450,000 (RECURRING/YEAR)

EQUIPMENT CATEGORY:

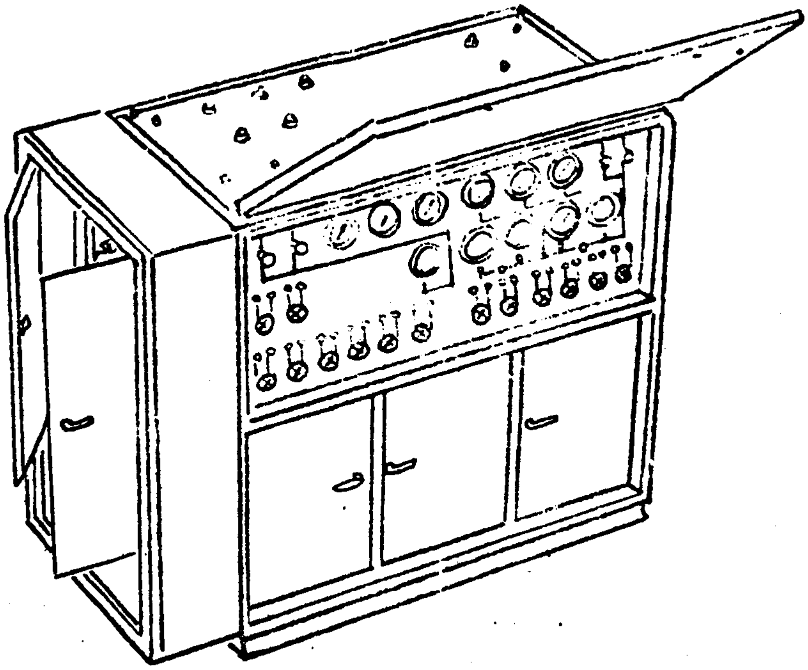
NEW X WTR MODIFIED ______ AS IS X ETR

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.7.1 - .4	TPF/KSC	1 GFE
1.1.7, 6-9	PPF/WTR	1
1.1.8 ALL	Factory	1 GFE
1.1.9 ALL	MCF/KSC	1 GFE
	MCF/WTR	1

TOTAL REQUIRED 5 TOTAL COST $ 950,000



PROPULSION PNEUMATIC CONSOLE
(LAUNCH)

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: PNEUMATIC SKID LAUNCH EQUIPMENT NO. 162

FUNCTIONAL REQUIREMENT(S):

Provide regulated gas supplies to vehicle for pressurization of pneumatic and propellant systems for pad checkout and launch.

EQUIPMENT DESCRIPTION:

Pneumatic console such as DSV-4B-432A modified for special Tug requirements.

COST $ 50,000 (DESIGN AND DEVELOPMENT)

$ 450,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

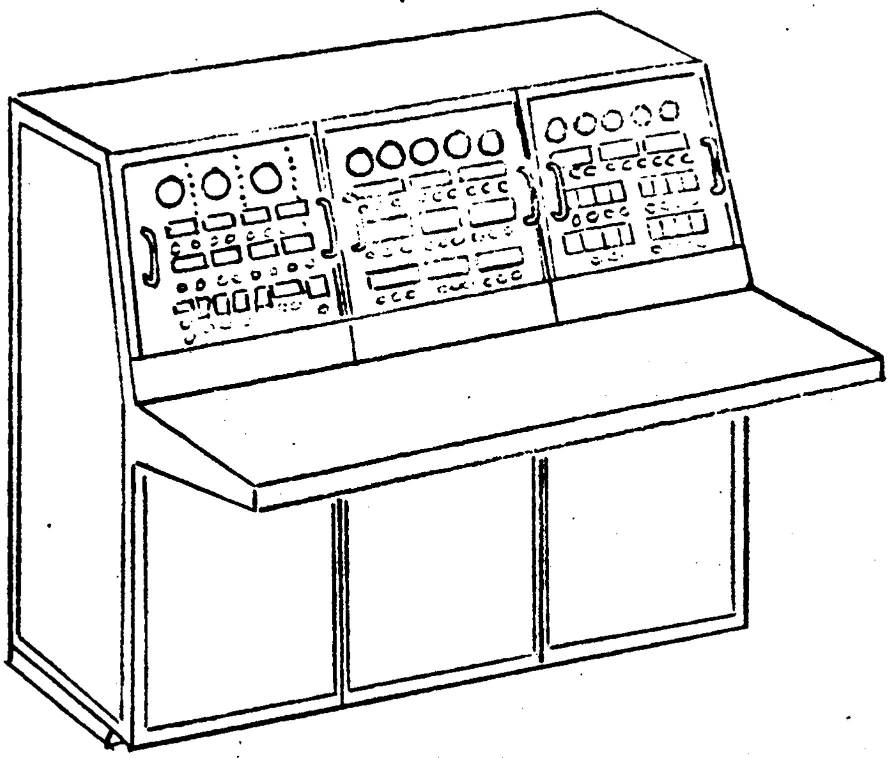
NEW X WTR MODIFIED ______ AS IS X GFE ETR

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.4.2	Launch Area/KSC	2 GFE
2.4.3	Launch Area/WTR	1

TOTAL REQUIRED 3 TOTAL COST $ 500,000



PROPELLANT OR PNEUMATIC CONTROL CONSOLE

GSE DESCRIPTION SHEET

NAME: PROPELLANT OR PNEUMATIC CONTROL CONSOLE EQUIPMENT NO. 163

FUNCTIONAL REQUIREMENT(S):

Controls and pneumatic regulated gas supplies for vehicle pressurization of pneumatics and propellant systems. Used for checkout, purge, and pressure checks and loading of pneumatics into Tug vehicle. Monitors propellant loading and unloading. Capable of semi-automatic or manual loading of propellants.

EQUIPMENT DESCRIPTION:

Three bay console with intercom, light and indicators, switches, and alpha numerical display, and associated circuitry. (Similar to DSV-4B-233.)

COST PER UNIT: $ 339,000 (NON-RECURRING)

$ 334,000 (RECURRING/YEAR)

EQUIPMENT CATEGORY:

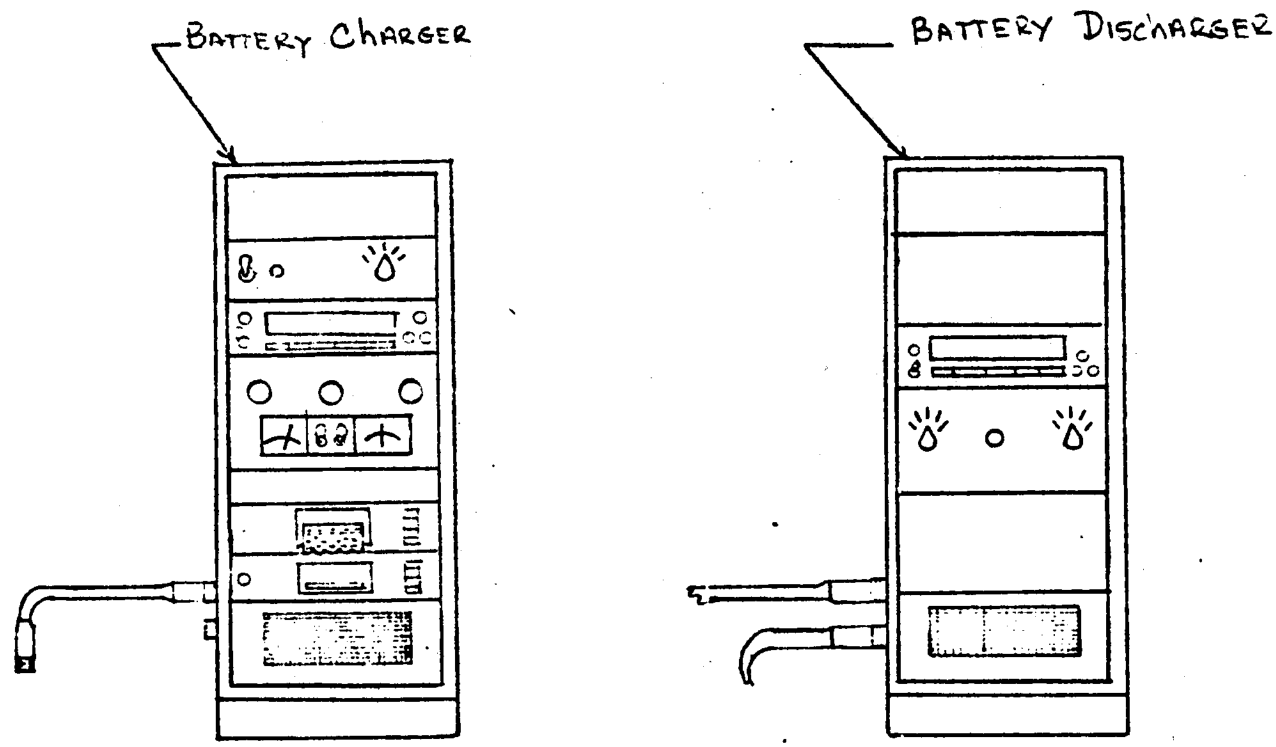
NEW X WTR MODIFIED ______ AS IS X ETR

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.7.1, -.4	TPF/KSC	1 GFE
1.1.7.6 - 9	Launch Pad/KSC	2 GFE
1.1.8 ALL	PPF/WTR	1
1.1.9 ALL	MCF/KSC	1 GFE
2.4.2	Factory	1
	MCF/WTR	1

TOTAL REQUIRED 7 TOTAL COST $ 1,007,000



BATTERY CHECKOUT KIT

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: BATTERY CHECKOUT KIT EQUIPMENT NO. 164

FUNCTIONAL REQUIREMENT(S):

Provide equipment required to checkout primary and/or rechargeable batteries. Battery activation, cell/battery voltage and current checks with/without load (or during charging). Provide heater power measure, heater current, and battery temperature.

EQUIPMENT DESCRIPTION:

Composed of work platform; two electronic equipment racks, test cables, and test connectors. Electronic racks consist of power supply, battery charger, fans, load bank digital voltmeters line printer and sequencer for automatic operation (similar to DSV-4B-171).

COST PER UNIT: $ 50,000 (NON-RECURRING)

$ -0- (RECURRING/YEAR)

EQUIPMENT CATEGORY:

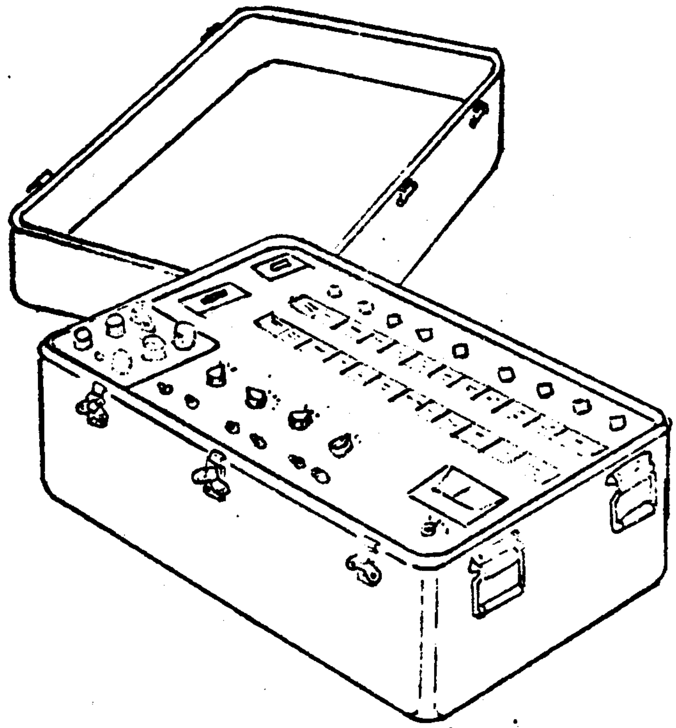
NEW ________ MODIFIED X AS IS X GFE

1ST YEAR REQ'D ________ NUMBER AVAILABLE ________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.13	KSC (TPF)	1
	WTR (PPF)	1

TOTAL REQUIRED 2 TOTAL COST $ 50,000



SPACECRAFT SIMULATOR

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: SPACECRAFT SIMULATOR **EQUIPMENT NO.** 168

FUNCTIONAL REQUIREMENT(S):

Functionally simulates Tug/Spacecraft interface for verification of electrical parameters.

EQUIPMENT DESCRIPTION:

Portable tester containing encoder, decoder and load test circuits.

COST $ 150,000 (DESIGN AND DEVELOPMENT)

$ 50,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

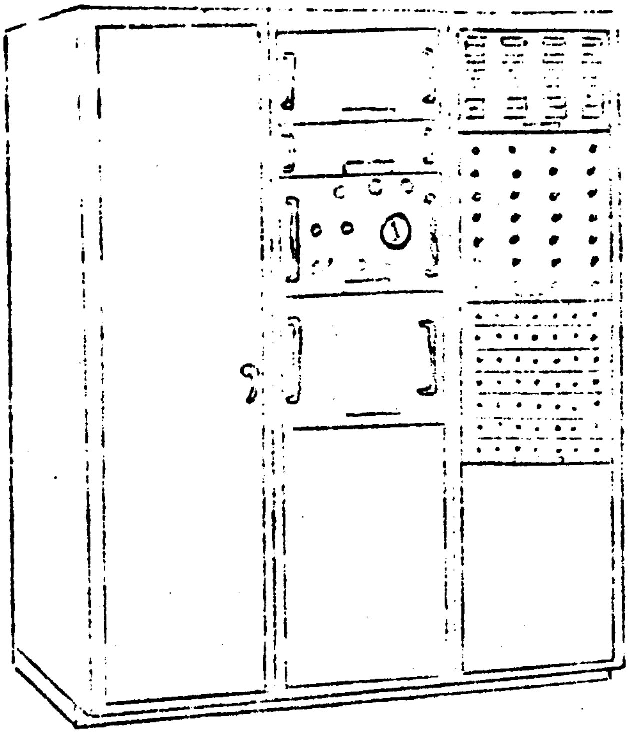
NEW x MODIFIED ______ AS IS ______

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.7.9	TPF/KSC	1
1.1.8.9	PPF/WTR	1
1.1.9.9	Factory	1

TOTAL REQUIRED 3 **TOTAL COST** $ 300,000



SPACE TUG SIMULATOR

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: SPACE TUG SIMULATOR EQUIPMENT NO. 169

FUNCTIONAL REQUIREMENT(S):

Functionally simulates Tug electrical parameters for verification of GSE, payloads and Shuttle interfaces.

EQUIPMENT DESCRIPTION:

3 Bay console interfacing with computer complex containing logic cards, encoder, decoder, and load test, test point assembly, indicator panels, logic power supply, path panel (similar to DSV-4B-132).

COST $ 400,000 (DESIGN AND DEVELOPMENT)

$ 100,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW x MODIFIED 30% AS IS 70%'

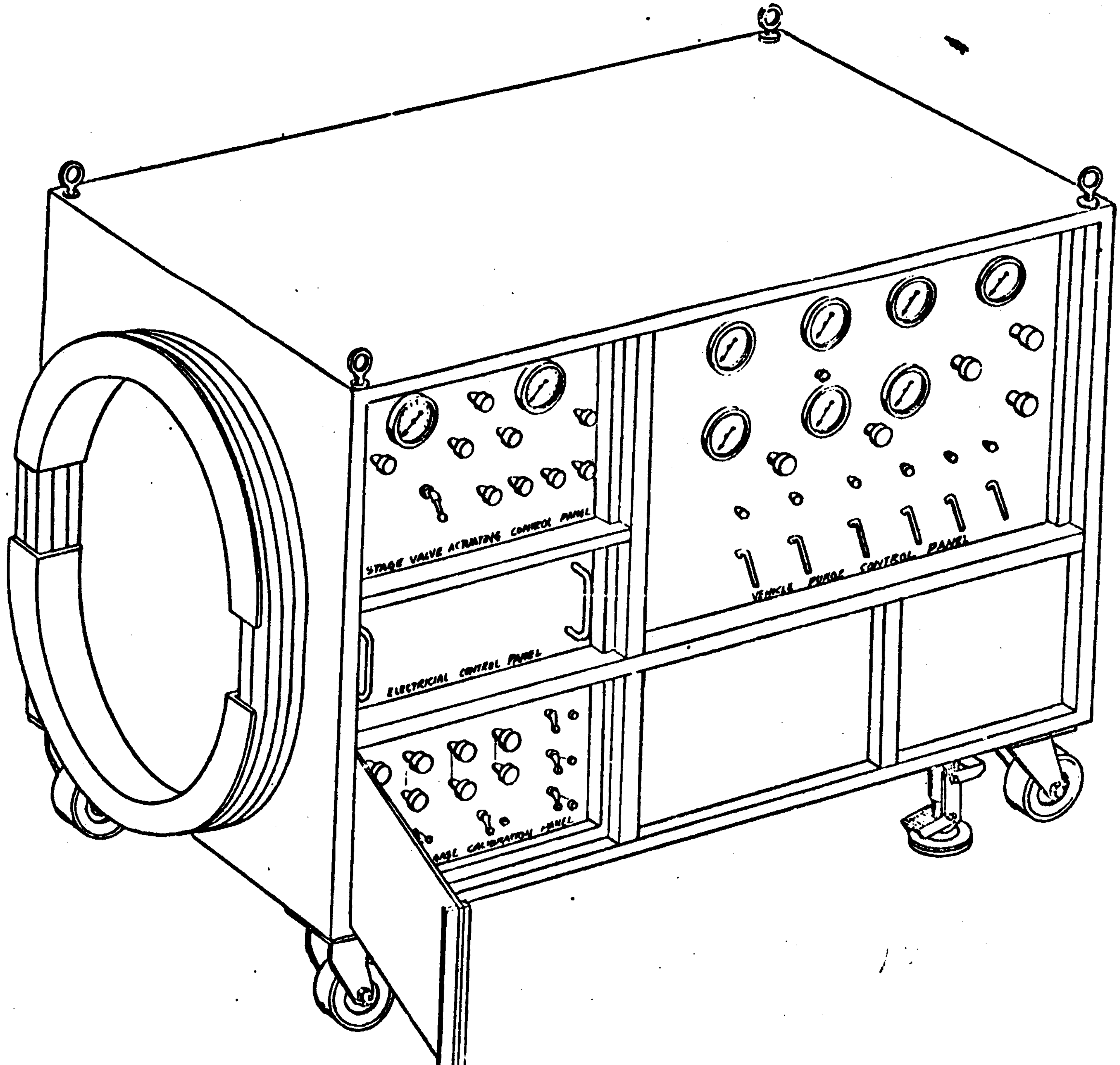
1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.7.9	TPF/KSC	1
1.1.8.9		
1.1.9.9	PPF/WTR	1
	Factory	1

TOTAL REQUIRED 3 TOTAL COST $ 700,000

E-99



Purge Kit, Stage Transport, Preparation A.C. – VPG

E-100

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: STAGE TRANSPORT PREPARATION GN_2 PURGE UNIT EQUIPMENT NO. 172

FUNCTIONAL REQUIREMENT(S):

Purges propellant system to an acceptable level for ground air transport, maintains proper nitrogen pressure at a level acceptable for stage purge and dry operation, provides the required valve actuation to protect the stage from adverse internal pressures.

EQUIPMENT DESCRIPTION:

Utilize DSV-4B-1865

COST $ -0- (DESIGN AND DEVELOPMENT)

$ -0- (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED ______ AS IS 100%

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
	KSC	1

TOTAL REQUIRED 1 TOTAL COST $ -0-

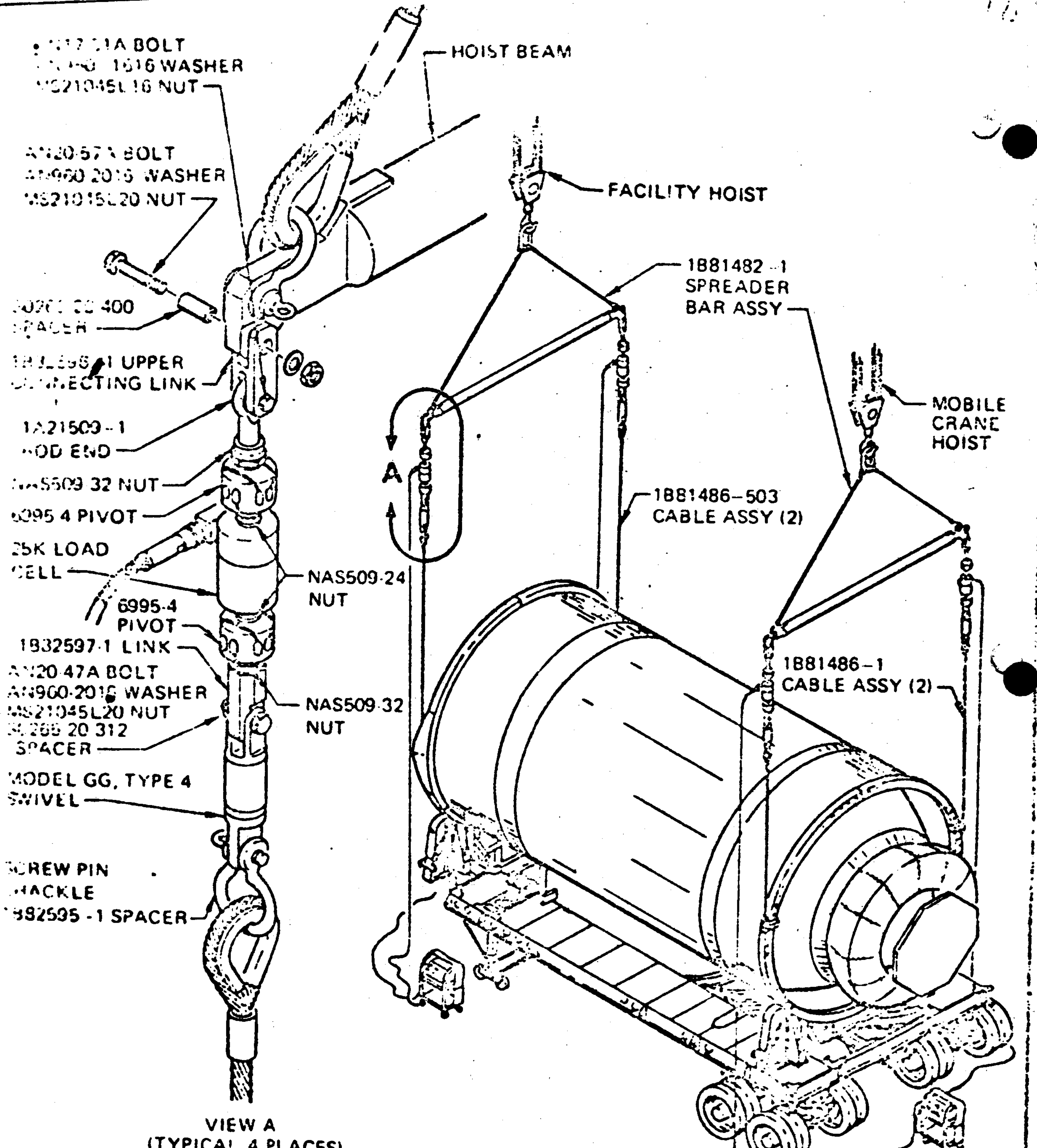


FIGURE 1.

McDONNELL DOUGLAS ASTRONAUTICS CO. WESTERN DIVISION HUNTINGTON BEACH, CALIFORNIA	SIZE A	CODE IDENT NO. 18355	DRAWING NO. STAGE WEIGHT & BALANCE KIT
	SCALE	REV	SHEET

E-102

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: STAGE WEIGH AND BALANCE KIT EQUIPMENT NO. 173

FUNCTIONAL REQUIREMENT(S):

Determines weight and center of gravity on stage and tilt table.

EQUIPMENT DESCRIPTION:

Similar to DSV-7-321 includes electronics from DSV-4B-345.

COST $ 5,000 (DESIGN AND DEVELOPMENT)

$ 75,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED 10% AS IS 90%

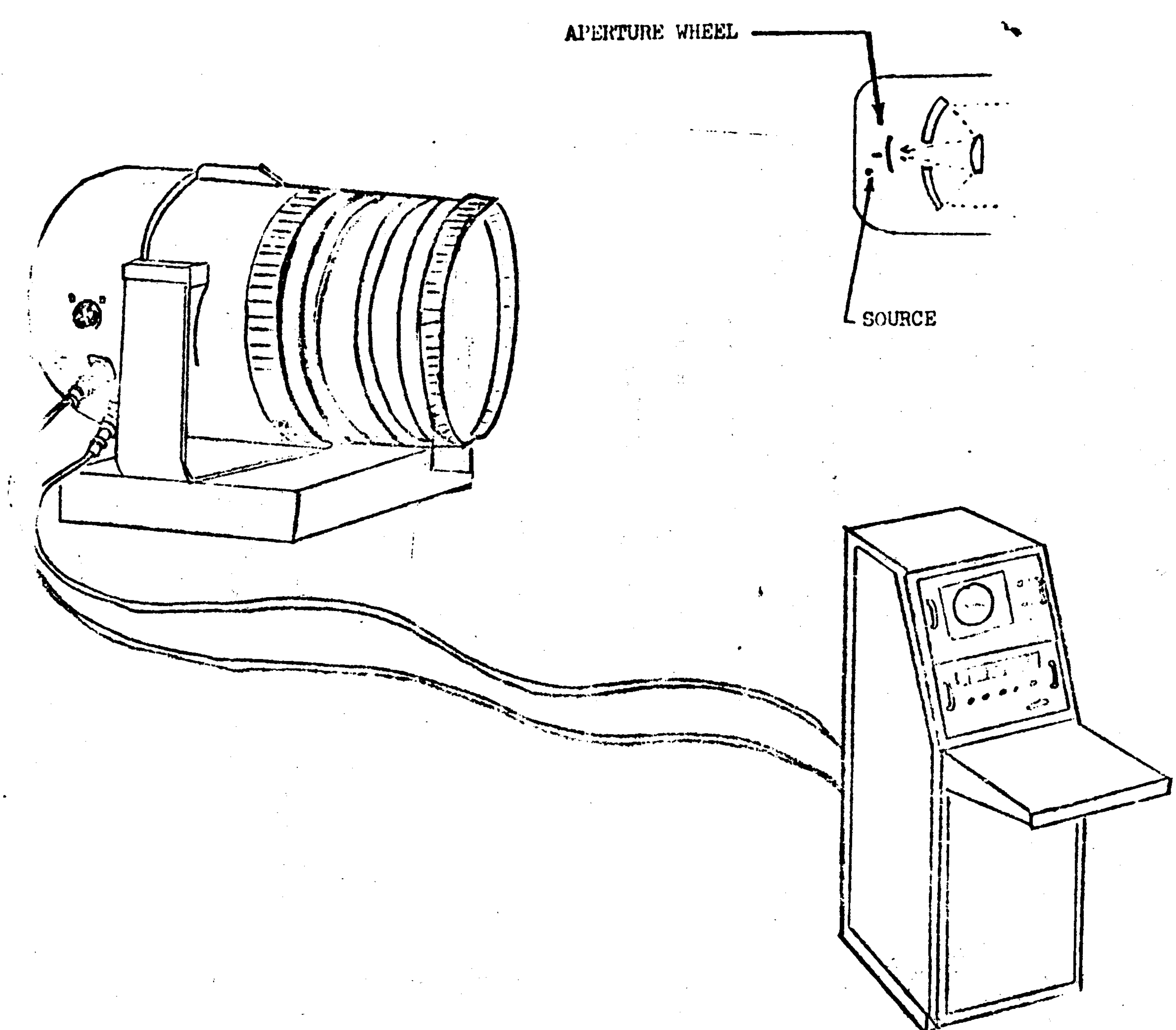
1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.15	TPF/KSC	1
	PPF/WTR	1

TOTAL REQUIRED 2 TOTAL COST $ 155,000

E-103



STAR TRACKER TEST SET

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: STAR TRACKER SIMULATOR **EQUIPMENT NO.** 174

FUNCTIONAL REQUIREMENT(S):

Simulates varying star magnitudes and position for optic integrity during ground checkout.

EQUIPMENT DESCRIPTION:

A portable tester that can be attached to the star tracker

COST $ 60,000 (DESIGN AND DEVELOPMENT)

$ 42,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW x MODIFIED ______ AS IS ______

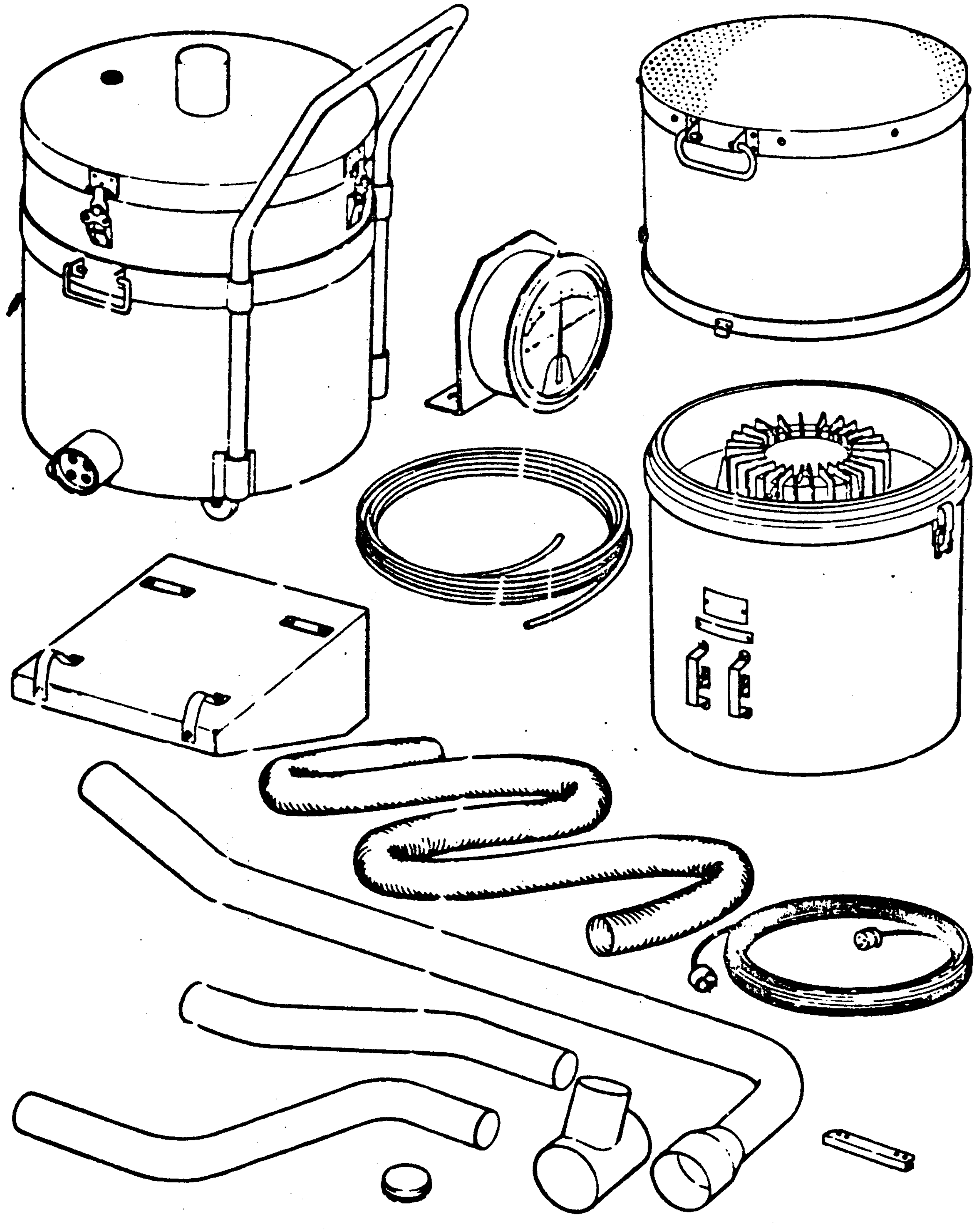
1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.13	TPF /KSC	1
	PPF/WTR	1
	Factory	1

TOTAL REQUIRED 3 **TOTAL COST $** 186,000

E-105



Desiccant Kit, Static

E-106

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: STATIC DESICCANT KIT **EQUIPMENT NO.** 175

FUNCTIONAL REQUIREMENT(S):

Provides contamination control of main propellant tanks when not pressurized

EQUIPMENT DESCRIPTION:

Breather assemblies with connecting hoses and clamps. Similar to DSV-4B-365 & DSV-4B-450 kits

COST $ 7000 (DESIGN AND DEVELOPMENT)

$ 1000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED x AS IS ______

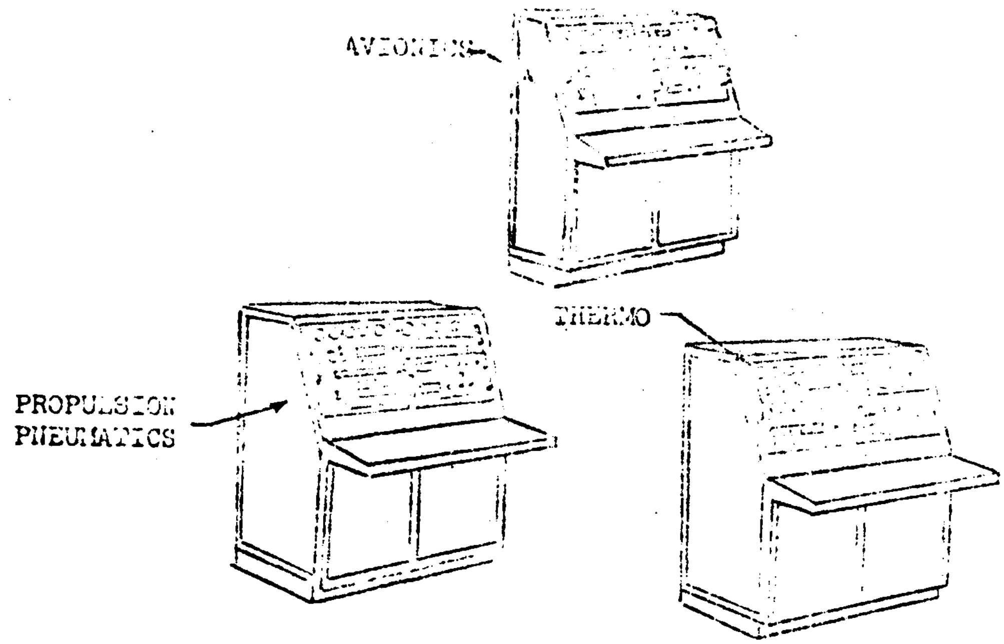
1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.23	KSC	4
	WTR	2
	Factory	2

TOTAL REQUIRED 8 **TOTAL COST $** 15,000

E-107



SUBSYSTEM MONITORING CONSOLES

GSE DESCRIPTION SHEET

NAME: SUBSYSTEM MONITORING CONSOLES EQUIPMENT NO. 176

FUNCTIONAL REQUIREMENT(S):

Monitors subsystem checkout and count down of avionics subsystems and displays status

EQUIPMENT DESCRIPTION:

Console with intercom, light and indicators, switches, and alpha numerical display (propulsion, avionics, thermo, pneumatics)

COST $ 70,000 (DESIGN AND DEVELOPMENT)

$ 15,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW x WTR MODIFIED ______ AS IS X ETR GFE

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.4.3	KSC	6
2.4.4	WTR	3

TOTAL REQUIRED 9 TOTAL COST $ 115,000

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: ENVIRONMENT CONDITIONING UNIT EQUIPMENT NO. 180

FUNCTIONAL REQUIREMENT(S):

Supplies conditioned air to trapped atmosphere sections of the Tug vehicle during manned occupancy in those sections.

EQUIPMENT DESCRIPTION:

Includes blower, controls, and directed ducting for air flow.

COST $ 110,000 (DESIGN AND DEVELOPMENT)

$ 242,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

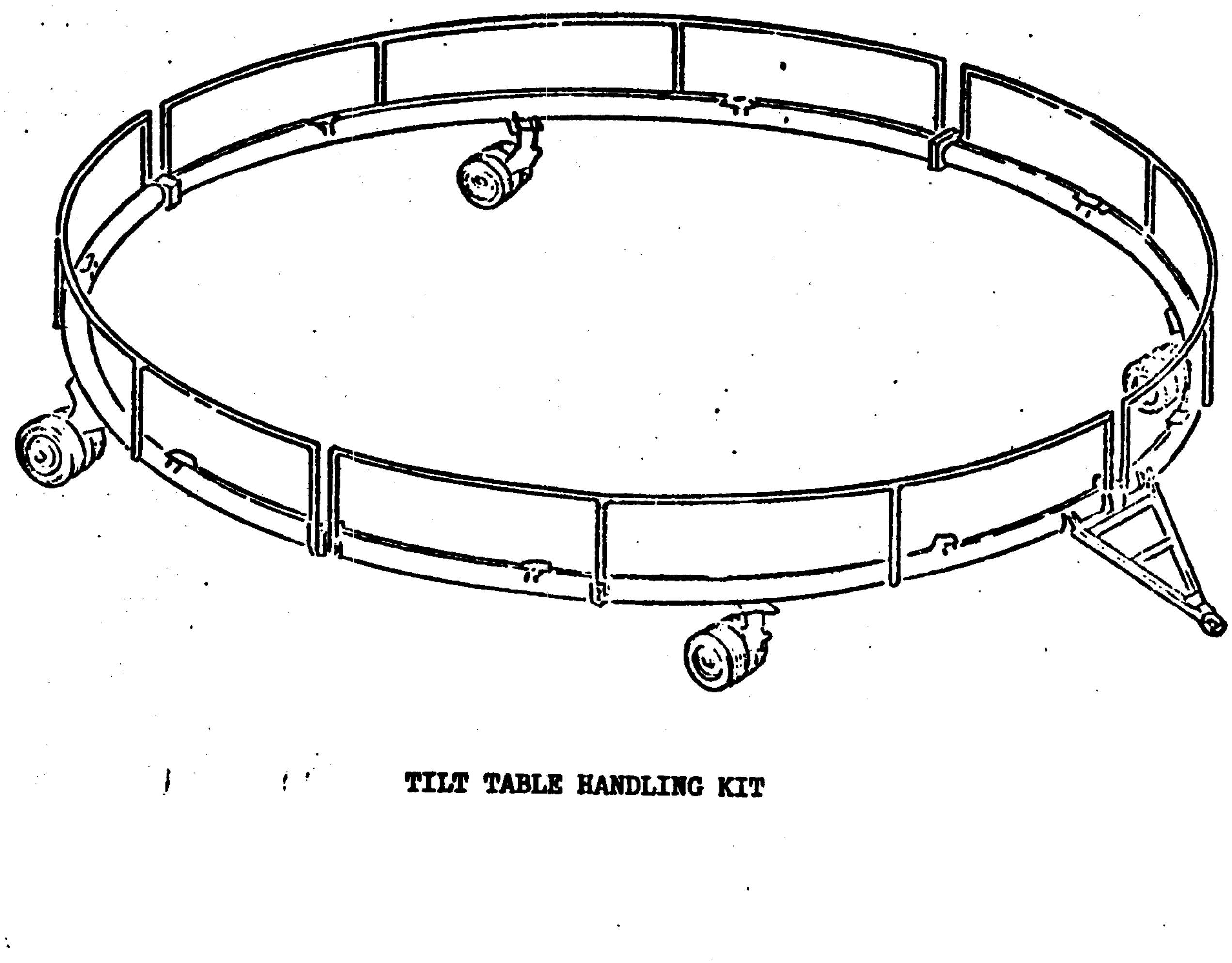
NEW ________ MODIFIED 10% AS IS 90% ETR

1ST YEAR REQ'D ________ NUMBER AVAILABLE ________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.5	TPF/KSC	1
	PPF/KSC	1
	PPF/WTR	1
	Factory	1

TOTAL REQUIRED 4 TOTAL COST $ 1,078,000



TILT TABLE HANDLING KIT

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: TILT TABLE HANDLING KIT EQUIPMENT NO. 181

FUNCTIONAL REQUIREMENT(S):

Provides means of transporting and handling stage aft interstage.

EQUIPMENT DESCRIPTION:

Similar to DSV-4B-307

COST $ 22,000 (DESIGN AND DEVELOPMENT)

$ 10,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW x MODIFIED ____ AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.16	TPF/KSC	2
1.1.17	PPF/WTR	1
	Factory	1

TOTAL REQUIRED 4 TOTAL COST $ 62,000

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: TRACTOR - TRANSPORTER EQUIPMENT NO. 182

FUNCTIONAL REQUIREMENT(S):

To pull transporter for Tug/SC

EQUIPMENT DESCRIPTION:

Three axle tractor with sto. 5th wheel — Ford C-800 or equiv.

COST $ 0 (DESIGN AND DEVELOPMENT)

$ 0 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED ______ AS IS X GFE at facility

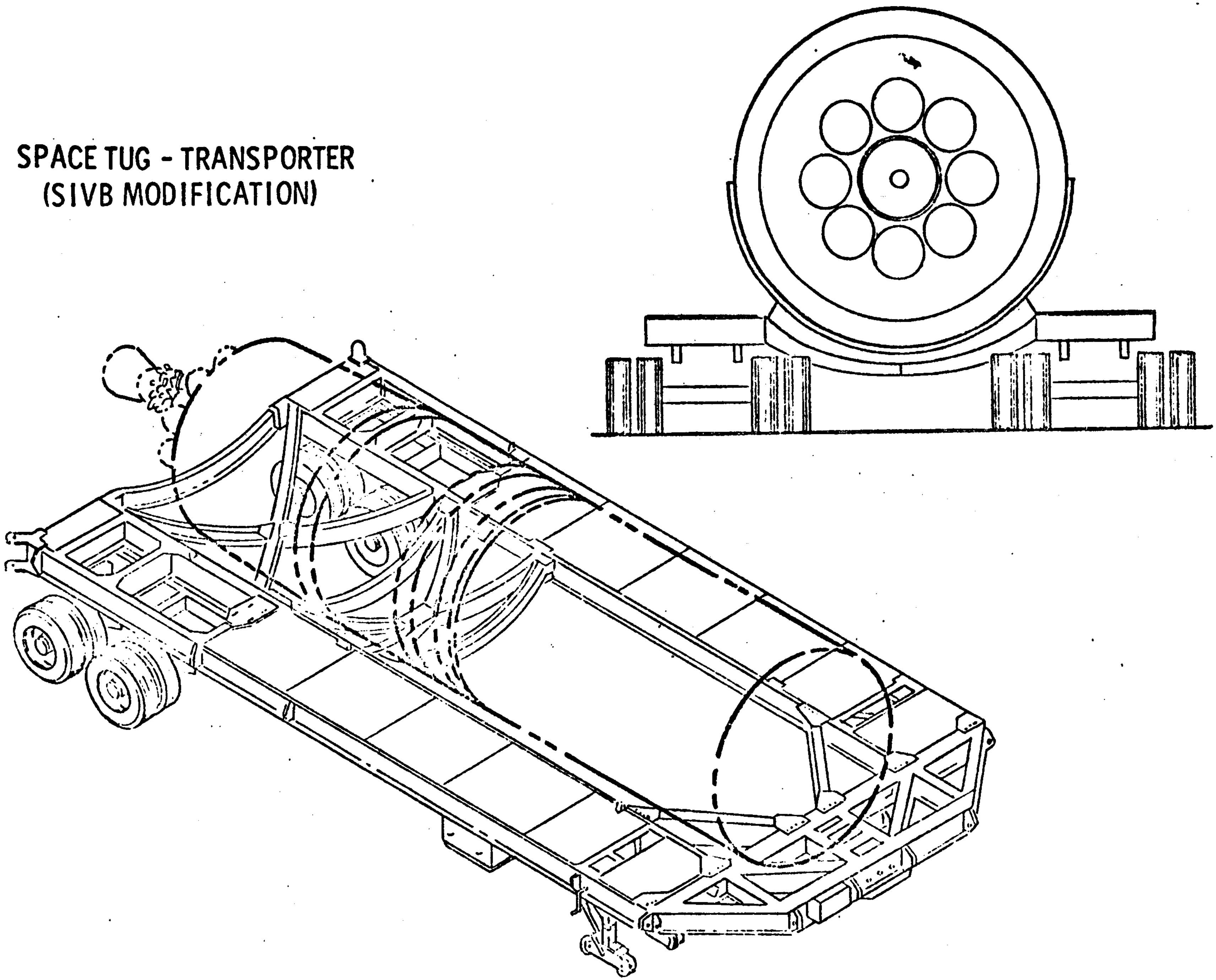
1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.2.1	KSC	2
1.1.25	WTR	2
2.1.4		
2.4.5		
2.4.8		

TOTAL REQUIRED 4 TOTAL COST $ -0-

SPACE TUG - TRANSPORTER
(SIVB MODIFICATION)



CONFIGURATION OPTION 03I

GSE DESCRIPTION SHEET

NAME: Transporter EQUIPMENT NO. 183

FUNCTIONAL REQUIREMENT(S):

To give horizontal support and provide mobility to the environmentally protected Tug with a secondary capability for roll and access.

EQUIPMENT DESCRIPTION:

A Saturn SIVB transporter modified to incorporate Saturn Workshop running gear and for provision of Tug compatible cradles.

COST PER UNIT: $ 10,000 (DESIGN AND DEVELOPMENT)

$ 25,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

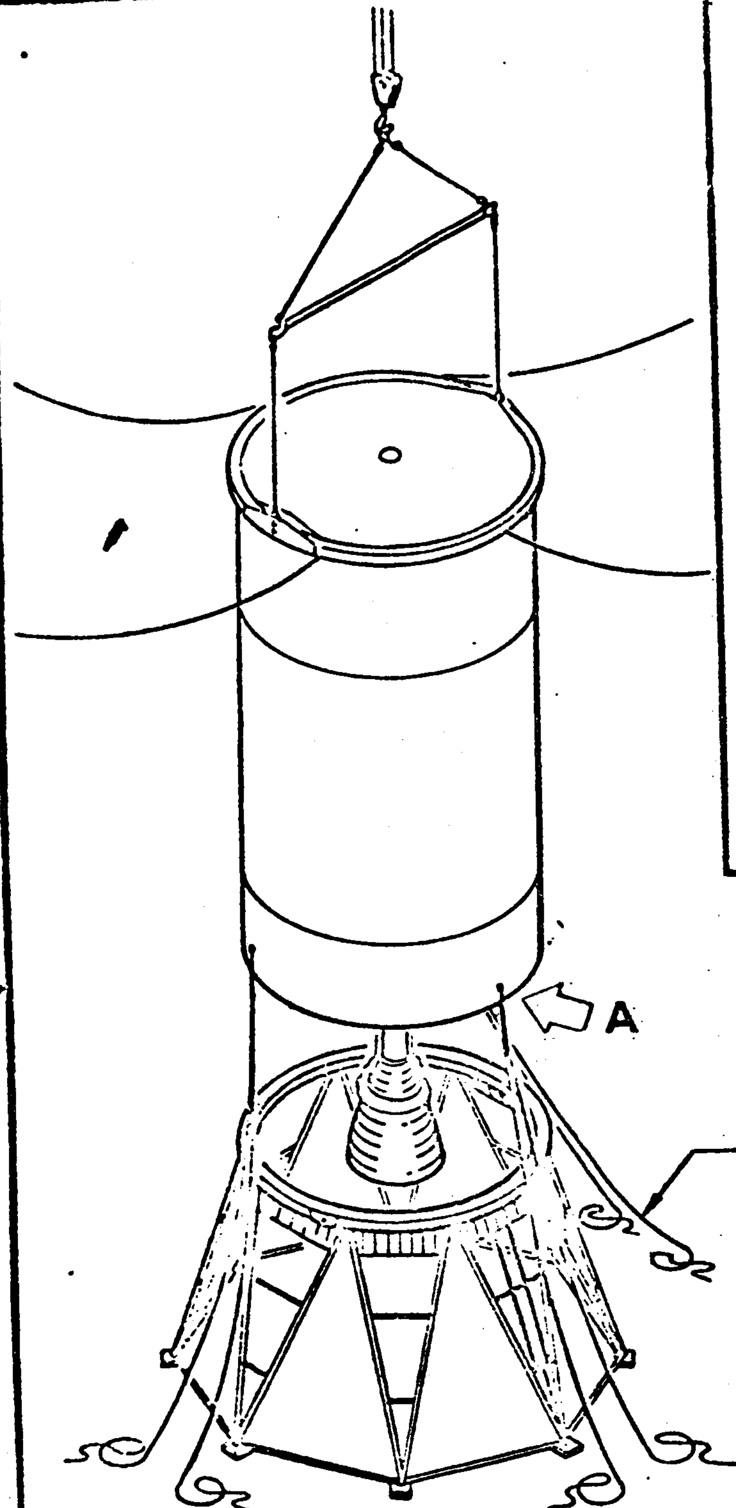
NEW ______ MODIFIED 20% AS IS 80%

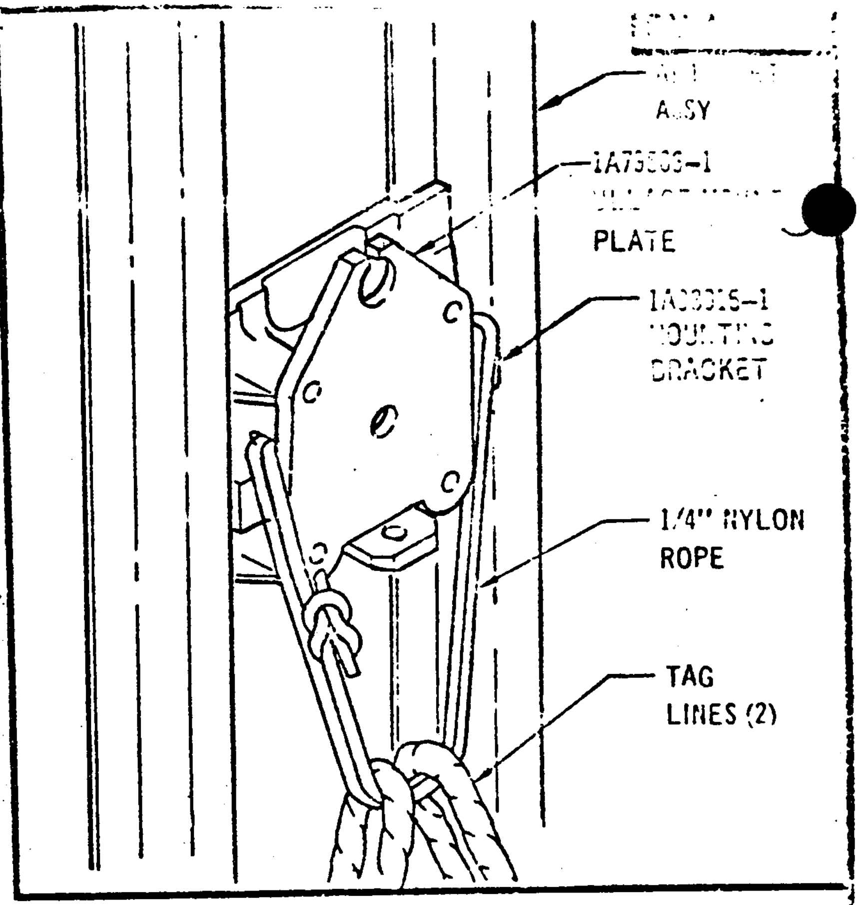
1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.4	KSC	3
1.1.2.1	WTR	2
1.1.2.2	Factory	1
1.1.25		
2.1.4		
2.3.4, 2.4.5 2.4.8		

TOTAL REQUIRED 5 TOTAL COST $ 135,000





VIEW A (3 PLACES)

CODE IDENT NO.	SIZE	
18355	A	TUG. SUPPORT KIT VERTICAL
		SHEET

CONFIGURATION OPTION All

GSE DESCRIPTION SHEET

NAME: TUG SUPPORT KIT (VERTICAL) EQUIPMENT NO. 184

FUNCTIONAL REQUIREMENT(S):

A welded structural steel stand to match Tug/Shuttle attach points and support Tug in a vertical position for SC mating.

EQUIPMENT DESCRIPTION:

Welded structural steel tube ~4,000 lbs.

COST $ 10,000 (DESIGN AND DEVELOPMENT)

$ 80,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

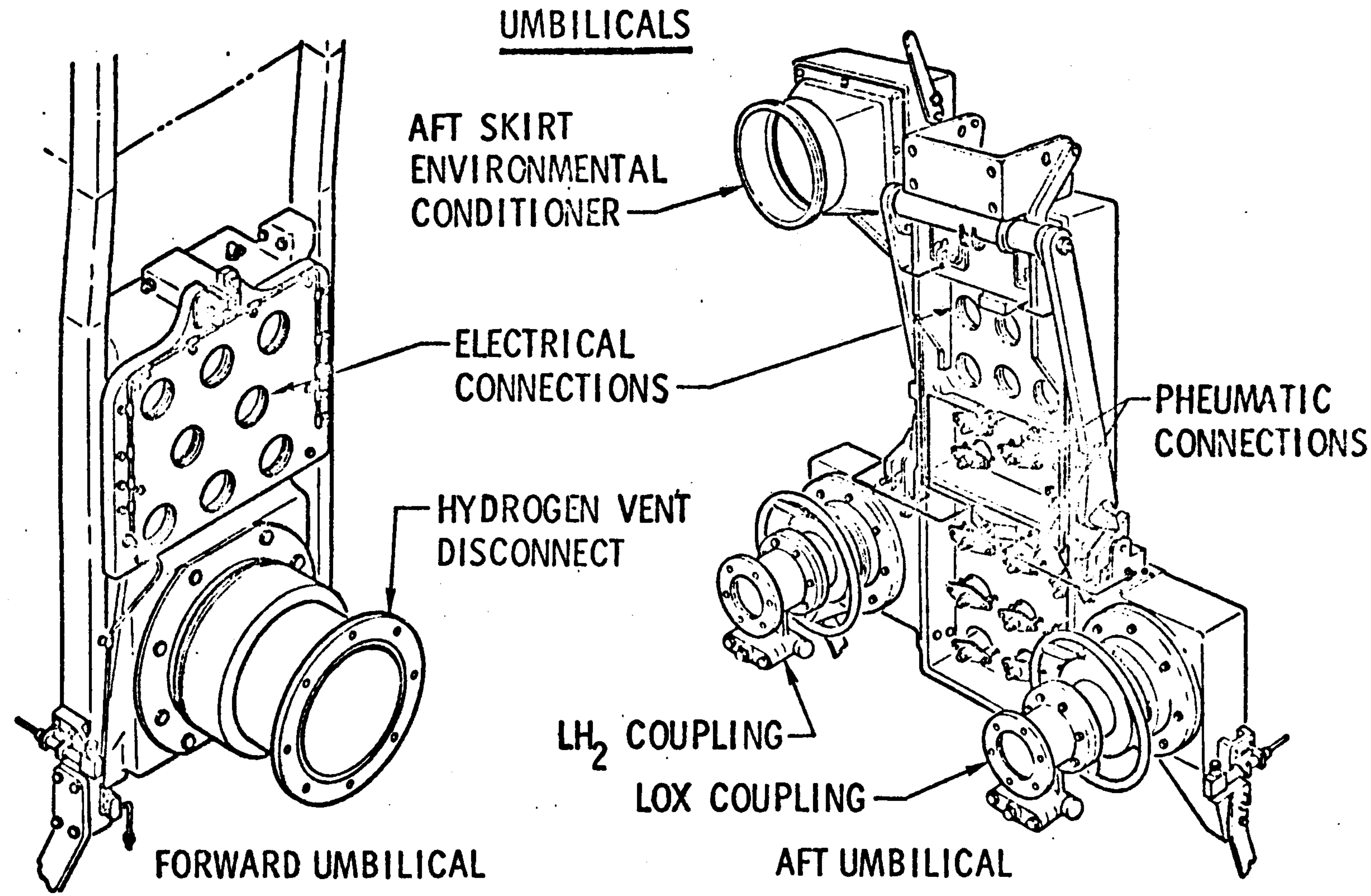
NEW ____ MODIFIED ____ AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.2.1.1	KSC	1
2.2.1.2	WTR	1
	Factory	1

TOTAL REQUIRED 3 TOTAL COST $ 250,000



UMBILICAL SYSTEM

CONFIGURATION OPTION ____

GSE DESCRIPTION SHEET

NAME: UMBILICAL SYSTEM **EQUIPMENT NO.** 185

FUNCTIONAL REQUIREMENT(S):

Connect test and checkout equipment to vehicle or to orbiter umbilical. Also, used for post flight safing.

EQUIPMENT DESCRIPTION:

Orbiter-half disconnects, ground-half disconnects (if different from orbiter-half), and hoses.

COST $ 400,000 (DESIGN AND DEVELOPMENT)

$ 50,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW X MODIFIED ____ AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.5	KSC (Launch pad)	2
2.3.2.2	TPF/KSC	1
2.3.9	MCF/KSC	1
2.4.2	Factory	1
2.4.5	PPF/WTR	1
	MCF/WTR	1

TOTAL REQUIRED 7 TOTAL COST $ 750,000

E-119

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: VOICE AND TIMING SYSTEM EQUIPMENT NO. 189

FUNCTIONAL REQUIREMENT(S):

Records timing and voice on Wide Band Magnetic Tape Recorder.

EQUIPMENT DESCRIPTION:

Similar to DSV-4B-772

COST $ 10,000 (DESIGN AND DEVELOPMENT)

$ 6,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW ________ MODIFIED ________ AS IS 100%

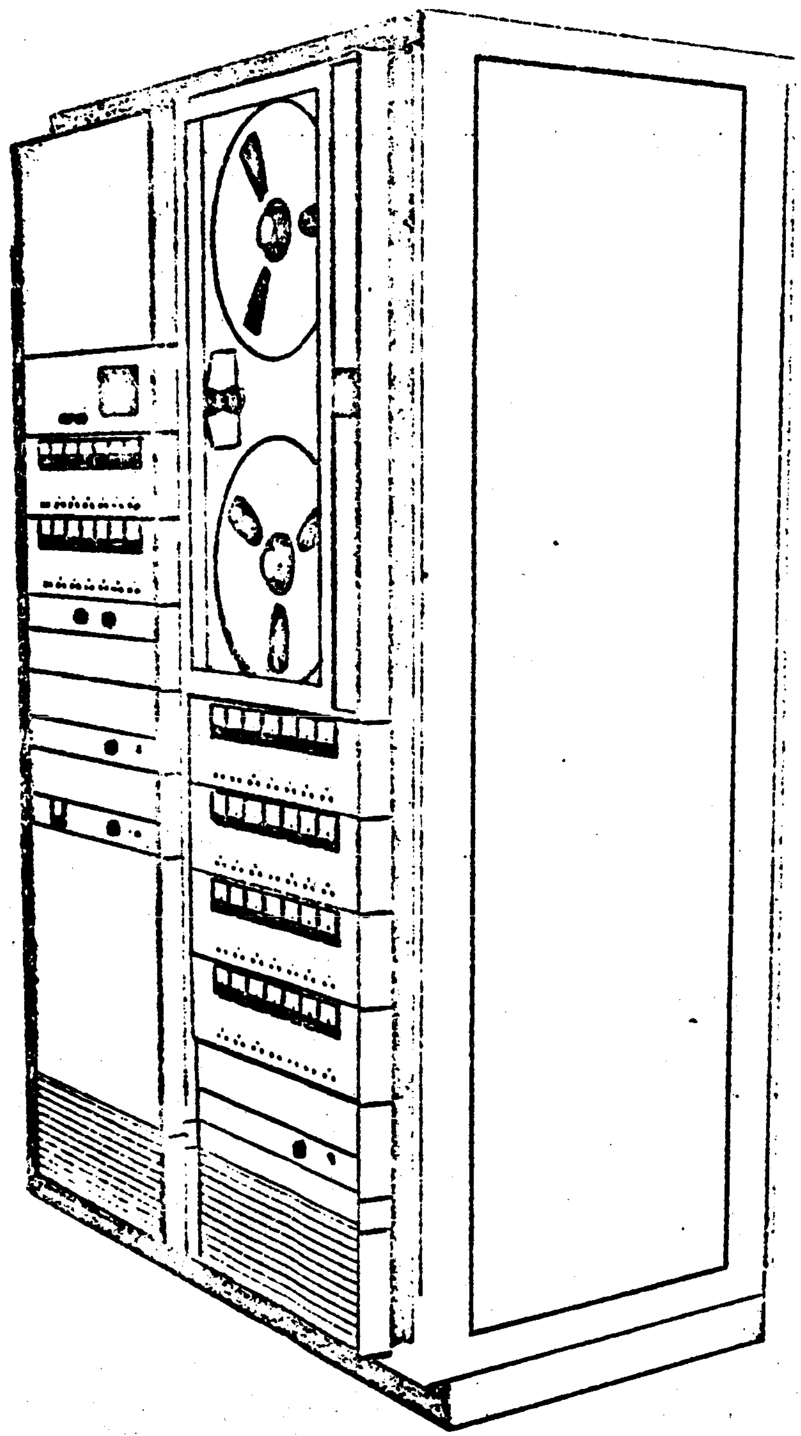
1ST YEAR REQ'D ________ NUMBER AVAILABLE ________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.4.3	KSC (BLOCKHOUSE)	1 GFE at ETR
	WTR (BLOCKHOUSE)	1

TOTAL REQUIRED 2 TOTAL COST $ 16,000

E-120



WIDE BAND MAGNETIC TAPE RECORDER

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: WIDE BAND MAGNETIC TAPE RECORDER EQUIPMENT NO. 190

FUNCTIONAL REQUIREMENT(S):

Receives and stores TM data for eventual playback and data analysis.

EQUIPMENT DESCRIPTION:

Similar to DSV-4B-127

COST $ 12,000 (DESIGN AND DEVELOPMENT)

$ 47,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW X WTR MODIFIED ________ AS IS X ETR

1ST YEAR REQ'D ________ NUMBER AVAILABLE ________

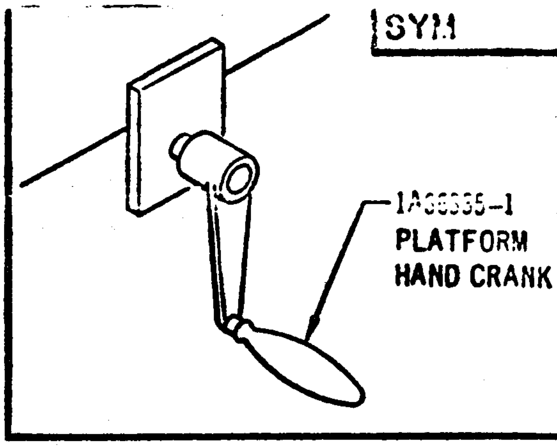
EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.7.9	TPF/KSC	1 GFE ETR
1.1.8.9		
1.1.9.9	MCF/KSC	1 GFE ETR
	PPF/WTR	1
	MCF/WTR	1

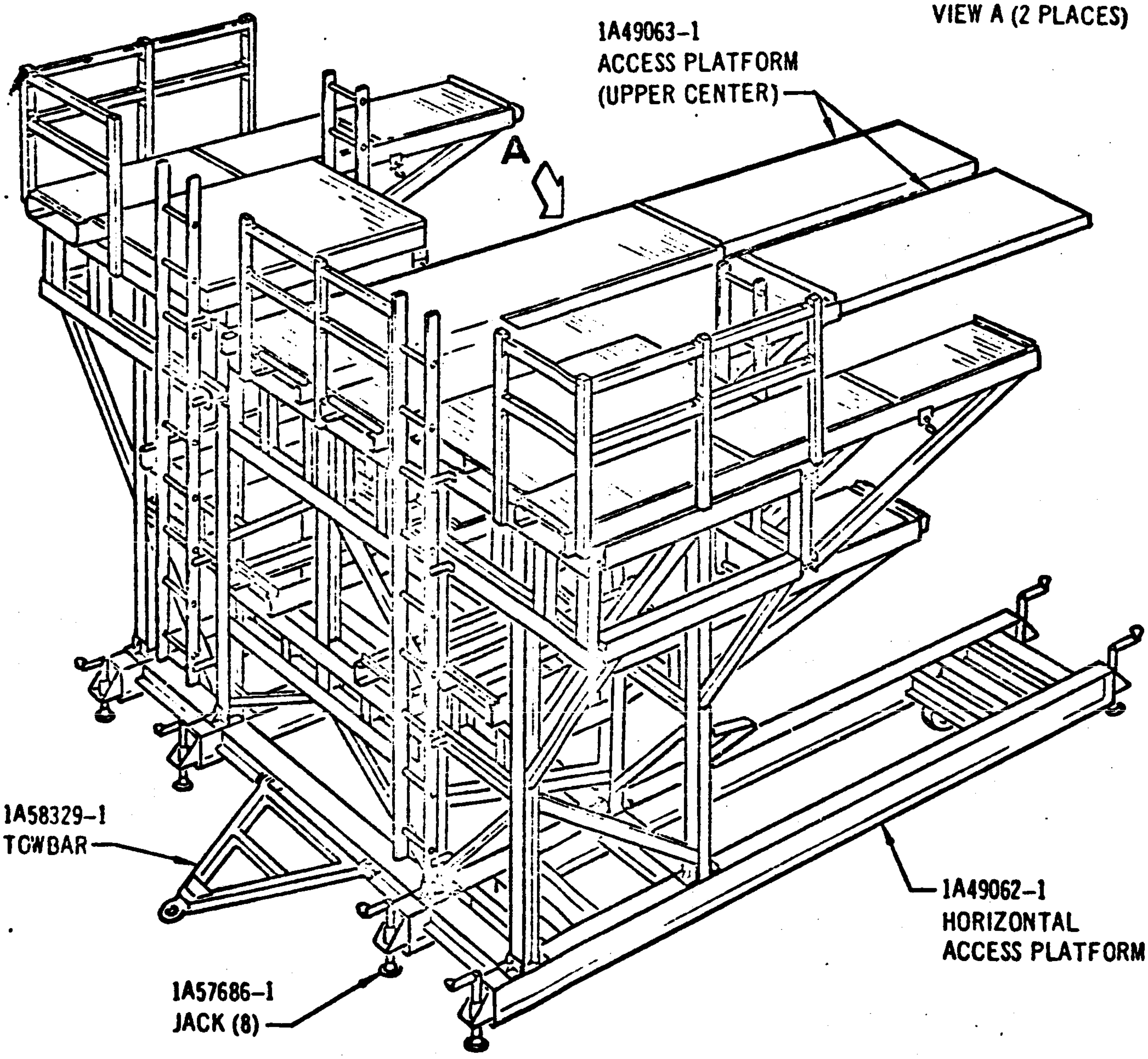
TOTAL REQUIRED 4 TOTAL COST $ 106,000

E-122

SYM



VIEW A (2 PLACES)



HORIZONTAL ACCESS PLATFORM

CODE IDENT NO.	SIZE	
18355	A	WORKSTAND KIT
		SHEET

E-123

CONFIGURATION OPTION All

GSE DESCRIPTION SHEET

NAME: WORKSTAND - KIT EQUIPMENT NO. 191

FUNCTIONAL REQUIREMENT(S):

To provide access to side and end of Tug (space craft) while installed on transporter.

EQUIPMENT DESCRIPTION:

Side access -- carbon steel angle and grating platform mated to transporter.

End access -- steel angle and grating structure with extensible platforms, mated to transporter.

COST $ 15,000 (DESIGN AND DEVELOPMENT)

$ 12,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW X MODIFIED ____ AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE 0

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.5	PPF/KSC	2
2.2.1.1	Storable Prop/KSC	1
2.2.2	TPF/KSC	3
2.3.2.2	PPF/WTR	3
3.1.1.	Storable Prop/WTR	1
	Factory	2

TOTAL REQUIRED 12 TOTAL COST $ 147,000

E-124

GSE DESCRIPTION SHEET

NAME: SECURITY VEHICLE EQUIPMENT NO. 192

FUNCTIONAL REQUIREMENT(S):

Provide on-site transportation for the security personnel accompaning DoD Spacecraft and secure Tug vehcle from classified facility to classified facility

EQUIPMENT DESCRIPTION:

Two axle motorized vehicle GFE at facility.

COST $ -0- (DESIGN AND DEVELOPMENT)

$ -0- (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW X MODIFIED ____ AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.2.1.1	KSC	3
2.3.1	WTR	3
2.3.4		
2.4.8		

TOTAL REQUIRED 6 TOTAL COST $ -0-

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: SIMULATION FLIGHT TEST COMPUTER PROGRAM EQUIPMENT NO. 301

FUNCTIONAL REQUIREMENT(S):

Simulated flight test (integrated system test) verifies Orbiter and Tug operate as a system. Verifies all interfaces in a simualted flight mode approximate 40K.

EQUIPMENT DESCRIPTION:

Magnetic tape or disk, listing and test procedure.

COST PER UNIT: $ 1,329,780 (NON-RECURRING)

$ 584,225 (RECURRING)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED ______ AS IS ______

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.3.9	MCF KSC	1
2.4.1	MCF WTR	1
2.4.3	Factory	1

TOTAL REQUIRED 3 TOTAL COST $ 1,914,005

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: GROUND CHECKOUT COMPUTER PROGRAMS EQUIPMENT NO. 302

FUNCTIONAL REQUIREMENT(S):

Executive control of Tug avionics computer and ground checkout computer.

Avionic computer, Executive and ground checkout computer executive.

EQUIPMENT DESCRIPTION:

Magnetic tape of disk; listing, and test procedure. 28K approximate memory instructions. (GSE computer checkout executive program 20K, flight computer checkout executive 8K.)

COST $ 290,640 (DESIGN AND DEVELOPMENT)

$ 29,064 (RECURRING)

EQUIPMENT CATEGORY:

NEW x MODIFIED ______ AS IS ______

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.3.9	KSC	1
2.4.1	WTR	1
2.4.3	Factory	1

TOTAL REQUIRED 3 TOTAL COST $ 319,704

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: GROUND CHECKOUT TUG PROCESSING FACILITY COMPUTER PROGRAMS   EQUIPMENT NO. 304

FUNCTIONAL REQUIREMENT(S):

Instrumentation system calibration & test. All system test. Subsystems test (used on long storage Tugs) Programs for power distribution test, communication test, ACPS, engine gimballing (steering), propulsion - pressurization, propellant Utilization, engine electronics, thermal control, data management, and guidance Navigation & Control

EQUIPMENT DESCRIPTION:

Magnetic tape or disk, listing, and test procedure. 256K approximate memory instructions. (Tug power on/off 10K, power distribution 25K, communications 20K, propellant utilization 6K, APCS 20K, engine gimballing 20K, propulsion 40K, data managment 20K, GN&C 15K, instrumentation system test and control 35K, all system test 45K.

COST $ 2,657,280 (DESIGN AND DEVELOPMENT)

$ 349,325 (RECURRING)

EQUIPMENT CATEGORY:

NEW x   MODIFIED ________   AS IS ________

1ST YEAR REQ'D ________   NUMBER AVAILABLE ________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.8.9	KSC	1
	WTR	1
	Factory	1

TOTAL REQUIRED 3   TOTAL COST $ 3,006,605

E-128

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: GROUND SUPPORT SELF-CHECK COMPUTER PROGRAMS EQUIPMENT NO. 305

FUNCTIONAL REQUIREMENT(S):

GSE Integrity checks and self-check programs

EQUIPMENT DESCRIPTION:

Magnetic tape or disk, listing, and test procedure. 65K approximate memory instructions. (GSE/Tug connector verification program 15K, GSE self check program 50K.)

COST $ 674,700 (DESIGN AND DEVELOPMENT)

$ 67,470 (RECURRING)

EQUIPMENT CATEGORY:

NEW x MODIFIED ________ AS IS ________

1ST YEAR REQ'D ________ NUMBER AVAILABLE ________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.5	KSC	1
2.3.9	WTR	1
	Factory	1

TOTAL REQUIRED 3 TOTAL COST $ 742,170

E-129

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: LAUNCH COUNTDOWN COMPUTER PROGRAMS EQUIPMENT NO. 306

FUNCTIONAL REQUIREMENT(S):

Simulated flight test program, propellant loading, and countdown program (power transfer, vehicle status and redline checks)

EQUIPMENT DESCRIPTION:

Magnetic tape or disk, listing test procedure, countdown manuals. 65K approximate memory instructions. (Propellant loading program 35K;countdown program 30K.)

COST $ 674,700 (DESIGN AND DEVELOPMENT)

$ 67,470 (RECURRING)

EQUIPMENT CATEGORY:

NEW x MODIFIED ______ AS IS ______

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.4.3	KSC	1
	WTR	1

TOTAL REQUIRED 2 TOTAL COST $ 742,170

E-130

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: SUPPORT SOFTWARE COMPUTER PROGRAMS **EQUIPMENT NO.** 307

FUNCTIONAL REQUIREMENT(S):

Checkout compiler - assembler, Tug/GSE function dictionary and calibration program, system simulation program, Tug flight computer emulator, orbiter/Tug checkout computer emulator, Fortran equation model program, trend data analysis program, flight program assembler and orbiter/Tug computer program assembler

EQUIPMENT DESCRIPTION:

Magnetic tape or disk, listing, and test procedure. 80K approximate memory instructions. (Data description program 10K, dictionary program 10K, compiler/assembler program 60K.)

COST $ 830,400 (DESIGN AND DEVELOPMENT)

$ 83,040 (RECURRING)

EQUIPMENT CATEGORY:

NEW x MODIFIED ______ AS IS ______

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.3.9	KSC	1
2.4.1	WTR	1
2.4.3	Factory	1

TOTAL REQUIRED 3 TOTAL COST $ 913,400

E-131

CONFIGURATION OPTION 01

PTV GSE DESCRIPTION SHEET

WBS 32A-07-01

NAME: AEDC INTERFACE CABLE KIT EQUIPMENT NO. 308

FUNCTIONAL REQUIREMENT(S):

Instrumentation required to instrument Tug for propulsion test vehicle testing in J4 test cell at AEDC.

EQUIPMENT DESCRIPTION:

50 Instrumentation cables run between Tug and junction box. Also, 6 interface cables.

COST PER UNIT: $ 13,500 (NON-RECURRING)

$ 30,000 (RECURRING/YEAR)

EQUIPMENT CATEGORY:

NEW X MODIFIED ____ AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED

TOTAL REQUIRED ____ TOTAL COST $ 43,500

PTV GSE DESCRIPTION SHEET

WBS 32A-07-01

NAME: TUG TEST CELL HOLDING FIXTURE EQUIPMENT NO. 309

FUNCTIONAL REQUIREMENT(S):

Holding fixture to mount Tug in the J4 test cell at AEDC.

EQUIPMENT DESCRIPTION:

Tubular steel holding fixture that adapt to Tug and test cell.

COST PER UNIT: $ 8,750 (NON-RECURRING)

$ 6,000 (RECURRING/YEAR)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED ______ AS IS ______

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED

TOTAL REQUIRED ______ TOTAL COST $ 14,750

PTV GSE DESCRIPTION SHEET

WBS 32A-07-01

NAME: AEDC INTERFACE JUNCTION BOX EQUIPMENT NO. 310

FUNCTIONAL REQUIREMENT(S):

Instrumentation junction box required to interface with J4 test cell at AEDC.

EQUIPMENT DESCRIPTION:

Junction box with 500 twisted shielded wire and 60 connectors.

COST PER UNIT: $ 12,500 (NON-RECURRING)

$ 16,000 (RECURRING/YEAR)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED ______ AS IS ______

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED

TOTAL REQUIRED ______ TOTAL COST $ 28,500

CONFIGURATION OPTION 01

PTV GSE DESCRIPTION SHEET

WBS 32A-07-01

NAME: TEST SOFTWARE COMPUTER PROGRAMS EQUIPMENT NO. 311

FUNCTIONAL REQUIREMENT(S):

Test software to control the propulsion test vehicle testing in J4 test cell at AEDC.

EQUIPMENT DESCRIPTION:

Magnetic tape or disk, listing, and test procedure. (See attachment.)

COST PER UNIT: $ 20,760 (NON-RECURRING)

$ -0- (RECURRING/YEAR)

EQUIPMENT CATEGORY:

NEW X MODIFIED ___ AS IS ___

1ST YEAR REQ'D ___ NUMBER AVAILABLE ___

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
	AEDC J4 Test Cell	1

TOTAL REQUIRED ___ TOTAL COST $ 20,760

TEST SOFTWARE REQUIREMENTS (AEDC) J4 TEST CELL

A. Define instrumentation requirements

1. Assign data channels and speeds for analog data.
2. Assign discrete-channels.
3. Determine data recording requirements (tape recording, strip chart, and real time reduction via Raytheon 520 and IBM 360/50 computers).
4. Determine console real time data display requirements.
5. Determine checkout computer (IBM 360/44 data input requirements for real time test control and monitoring).

B. Define control parameters

1. Assign control functions for manual control panels in J4 test cell.
2. Assign checkout computer control functions (relay closures and logic level).

C. Define calibration data

1. Determine calibration for facility instrumentation (use trend data from other test programs).
2. Determine calibration for the test peculiar parameters.

It is assumed that AEDC J4 test cell provides channel assignments list, calibration data, signal routing requirements from existing support software programs. MDAC will have to provide inputs to these programs through Interface Control Documents (ICD).

COLD FLOW TEST

Develop a checkout/control program to perform the Cold Flow Test. This program to be executed on the IBM 360/44 computer will provide the following:

a. Automatically accomplish facility monitoring and control.
b. Initiate, monitor, and terminate cold flow per the design parameters.
c. Secure test article and facility.
d. Provide the emergency shutdown sequences.

This program is sized at 12,000 words which include limited real time documentation via a line printer.

GSE DESCRIPTION SHEET

NAME: MISSION CONTROL TUG SUBSYSTEM SOFTWARE EQUIPMENT NO. 312

FUNCTIONAL REQUIREMENT(S):

Provide software to drive displays for Tug subsystem status. Utilizing existing software programs at mission control and provide subroutines for Tug peculiar functions.

EQUIPMENT DESCRIPTION:

Card decks, listings, and magnetic tapes.

COST PER UNIT: $ 950,000 (NON-RECURRING) FOR NASA AND DOD COMBINED

$ 2,173,500

EQUIPMENT CATEGORY:

NEW ____ MODIFIED ____ AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
	NASA Mission Control	1
	DOD Mission Control	1

TOTAL REQUIRED ____ TOTAL COST $ 3,123,500

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: DOD MISSION CONTROL STATUS AND MONITORING STATIONS   EQUIPMENT NO. 313

FUNCTIONAL REQUIREMENT(S):

Provide Tug status to DOD mission control for providing up/down link commands. Provide subsystem status for trajectory and guidance, propulsion, electrical power, thermal, data management, test director, and rendezvous and docking functions.

EQUIPMENT DESCRIPTION:

Seven two bay sitdown consoles with cathode ray tube, alpha numerical displays, communications, and associated circuitry.

COST PER UNIT: $________ (NON-RECURRING)

$________ (RECURRING/YEAR)

EQUIPMENT CATEGORY:

NEW ________ MODIFIED ________ AS IS X GFE

1ST YEAR REQ'D ________ NUMBER AVAILABLE ________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
	DOD Mission Control	7

TOTAL REQUIRED ________   TOTAL COST $ -0-

GSE DESCRIPTION SHEET

NAME: NASA MISSION CONTROL STATUS MONITORING STATIONS EQUIPMENT NO. 314

FUNCTIONAL REQUIREMENT(S):

Provide Tug status to NASA mission control for providing up/down link commands. Provide subsystem status for trajectory and guidance; propulsion, electrical power, thermal, data management, test director, and rendezvous and docking functions.

EQUIPMENT DESCRIPTION:

Seven two bay sitdown consoles with cathode ray tubes, alpha numerical displays, communications, and associated circuitry.

COST PER UNIT: $________ (NON-RECURRING)

$________ (RECURRING/YEAR)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED ______ AS IS X GFE

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

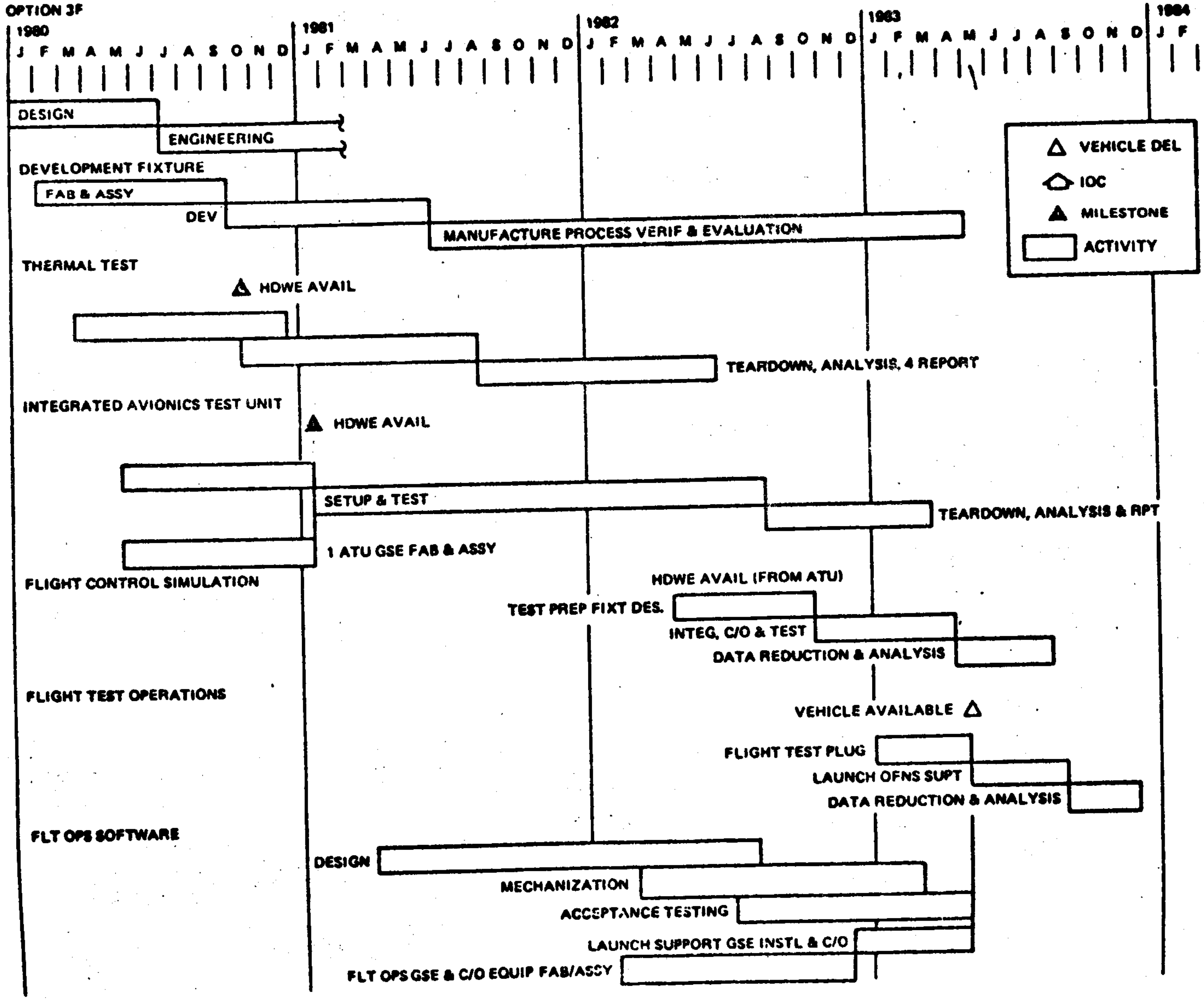
FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
	NASA Mission Control	7

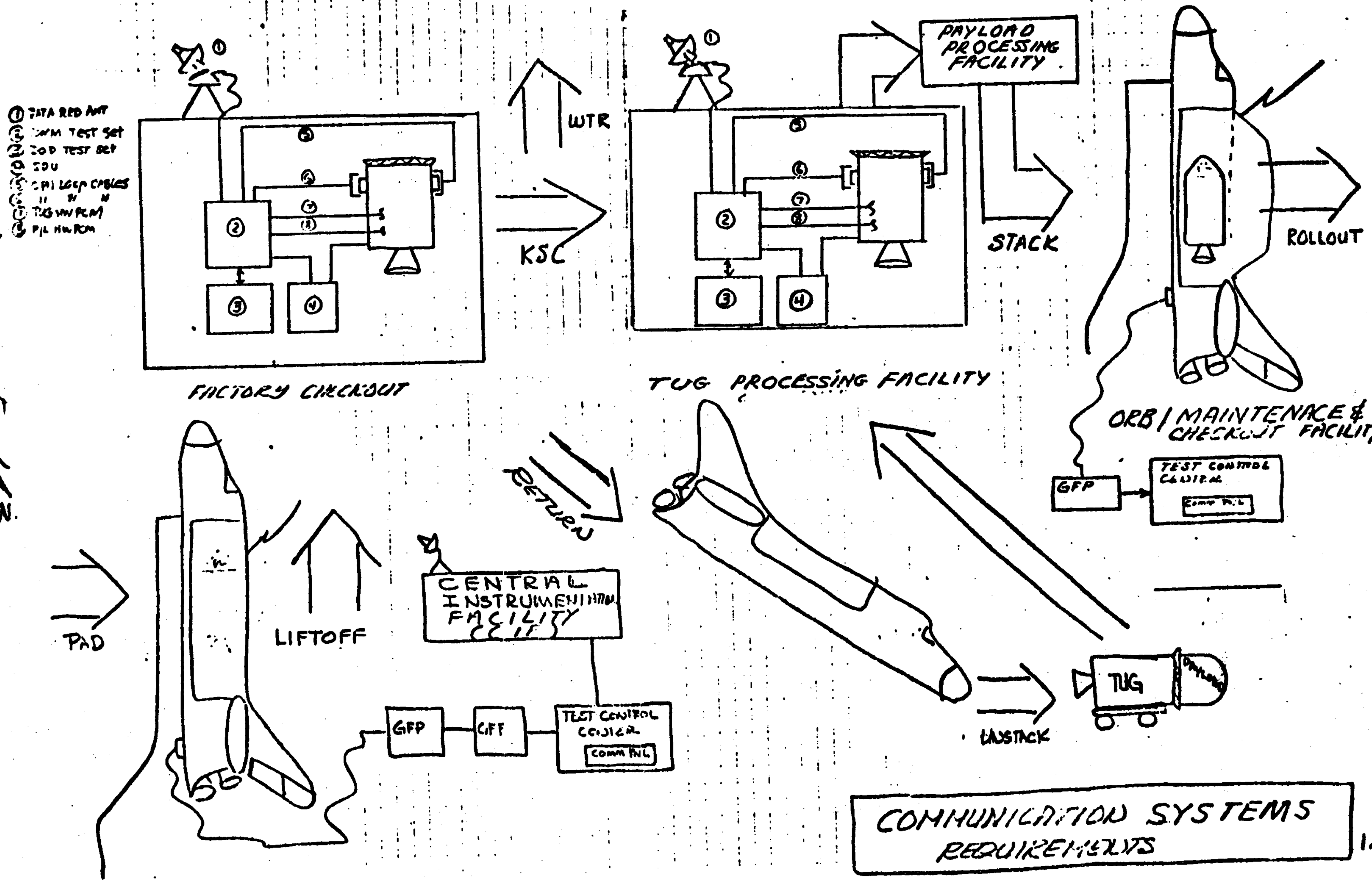
TOTAL REQUIRED ______ TOTAL COST $ -0-

TABLE OF CONTENTS

TABLE OF CONTENTS
(CONT'd)

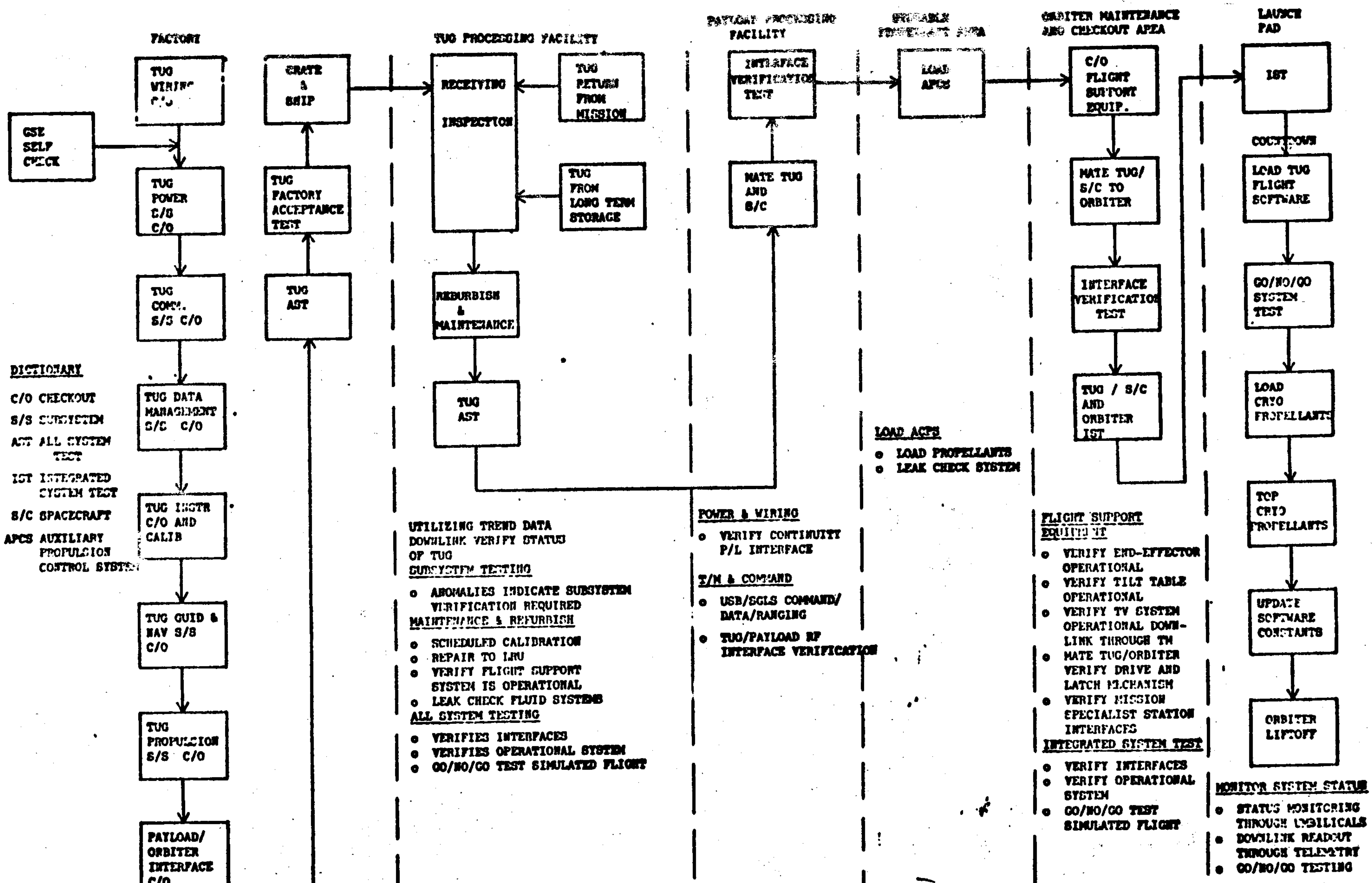
DEVELOPMENT SCHEDULE
OPTION 3F





COMMUNICATION SYSTEMS REQUIREMENTS

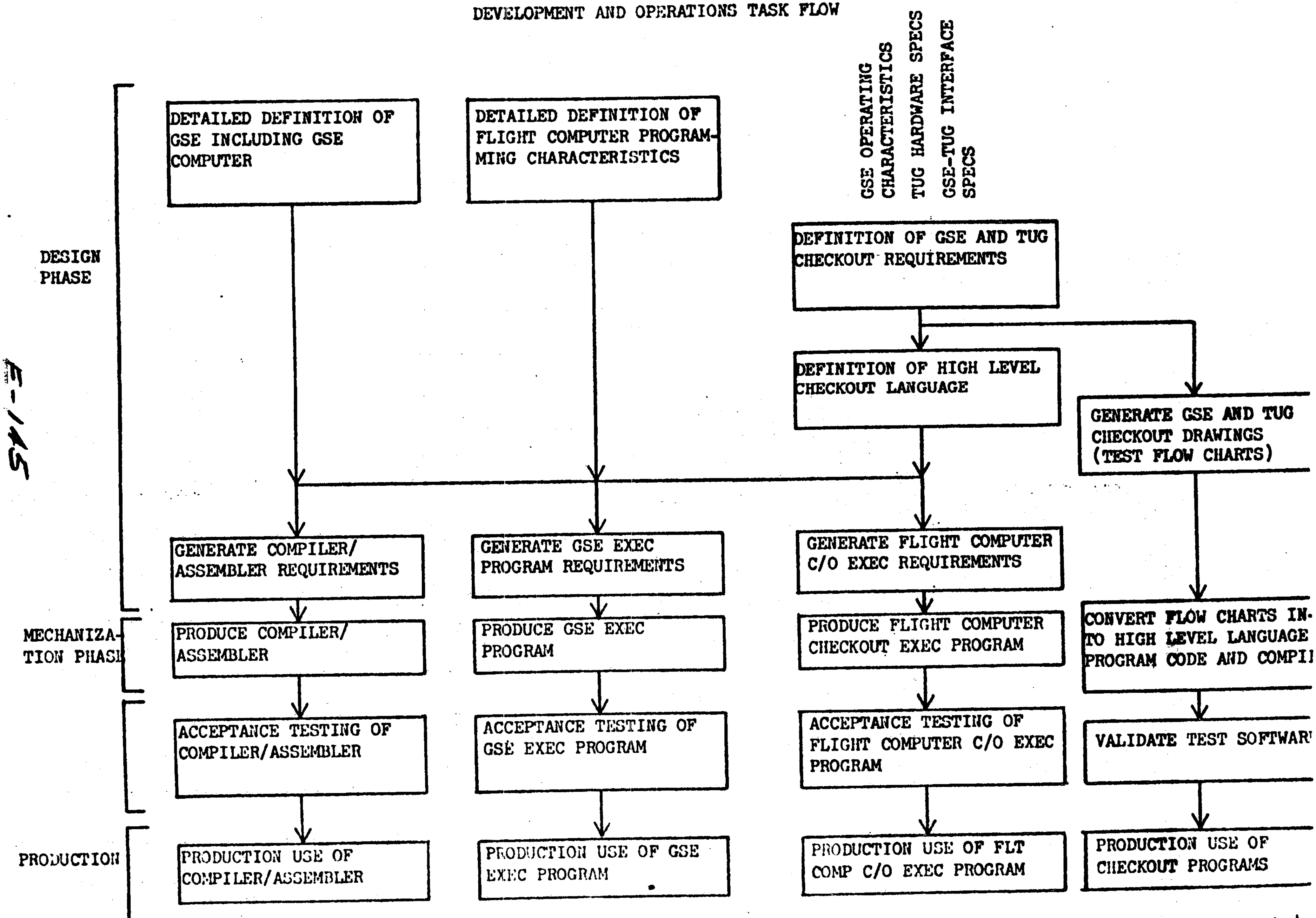
E-143



CHECKOUT AND INTERFACE VERIFICATION FLOW

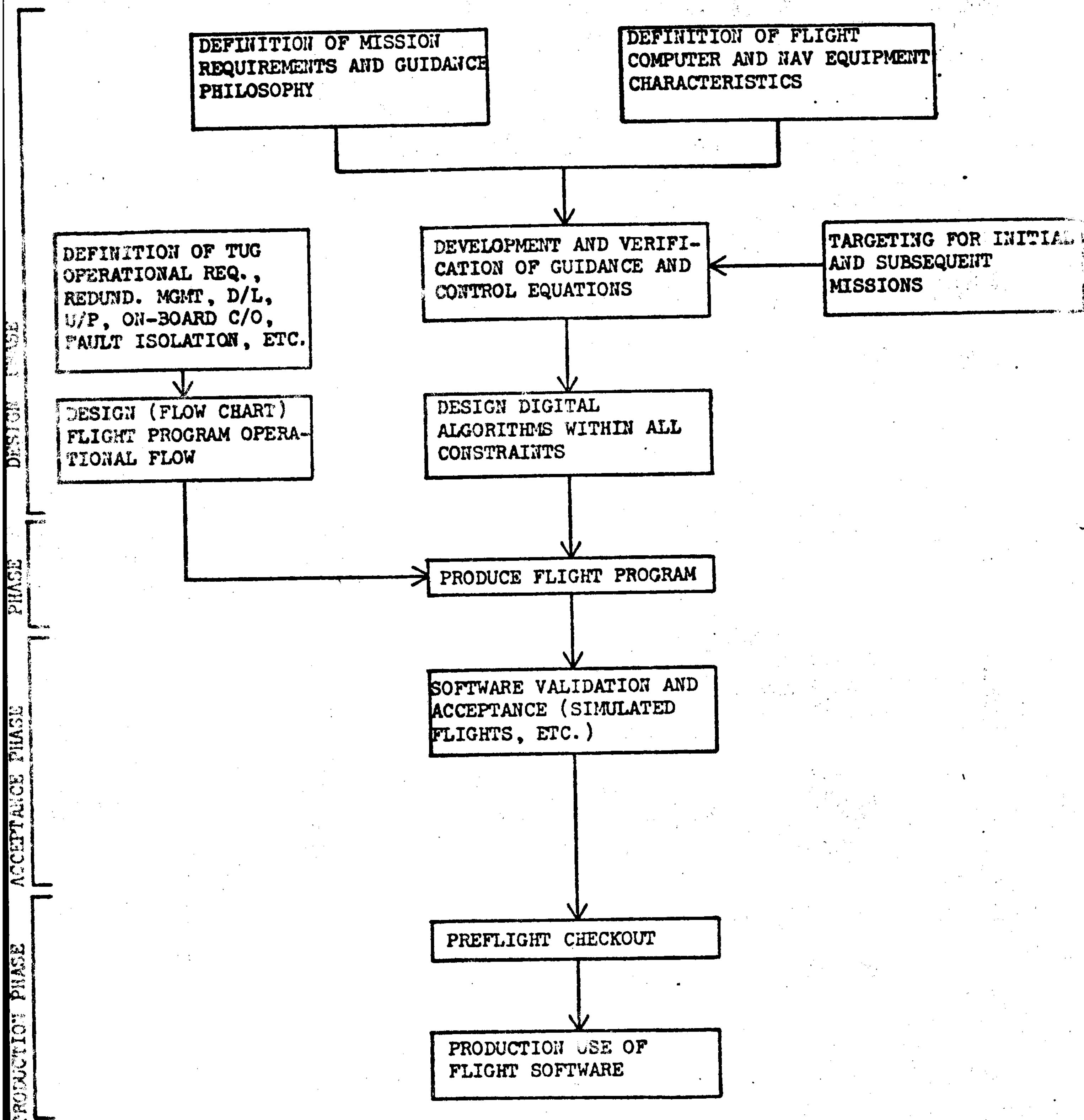
CHECKOUT SOFTWARE

DEVELOPMENT AND OPERATIONS TASK FLOW

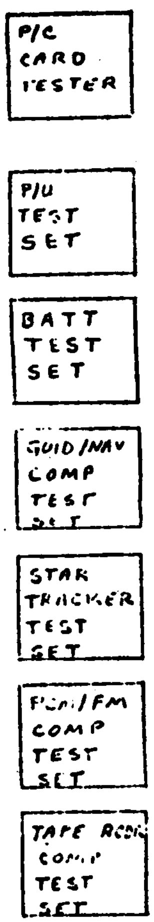


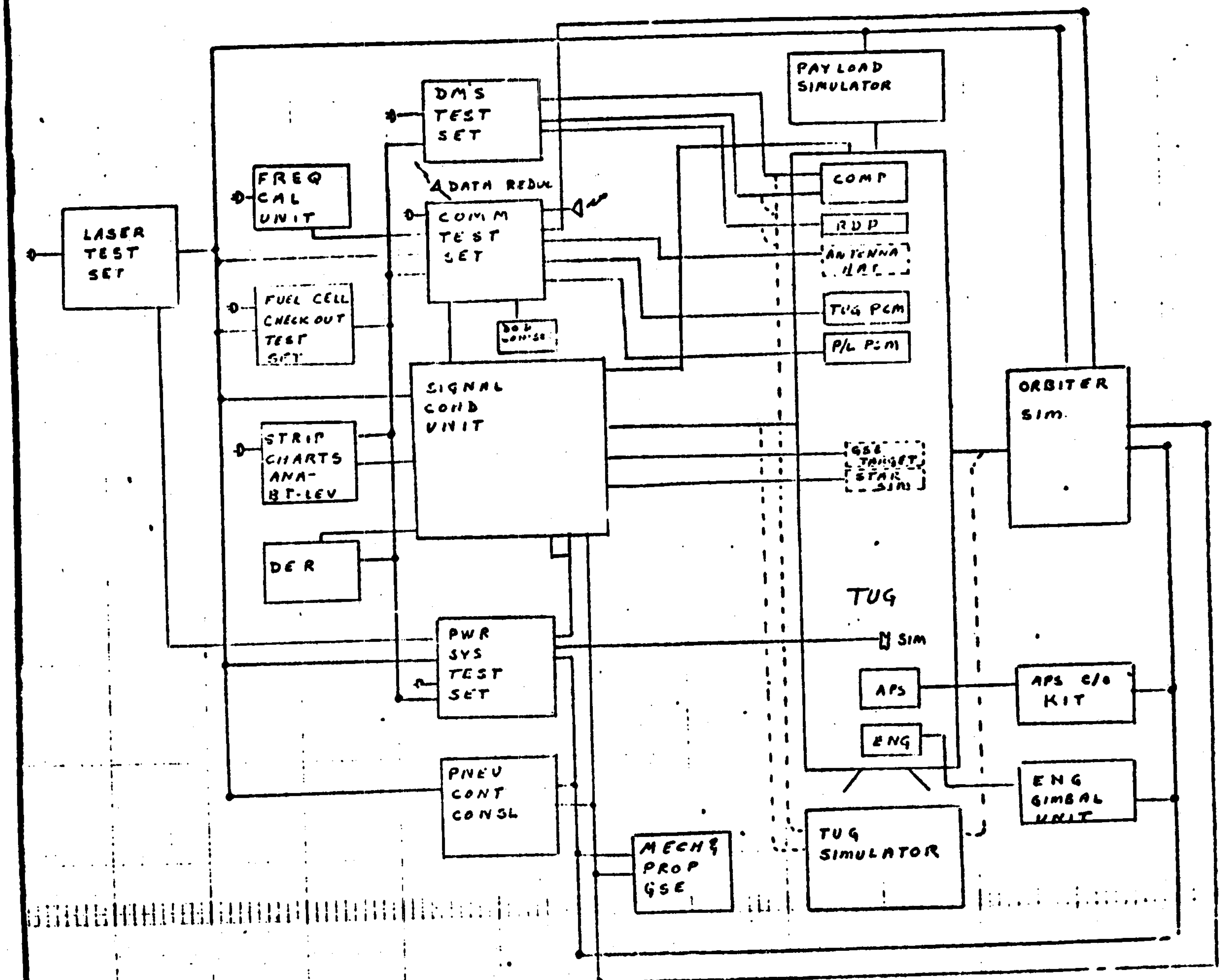
FLIGHT SOFTWARE

DEVELOPMENT AND OPERATIONS TASK FLOW



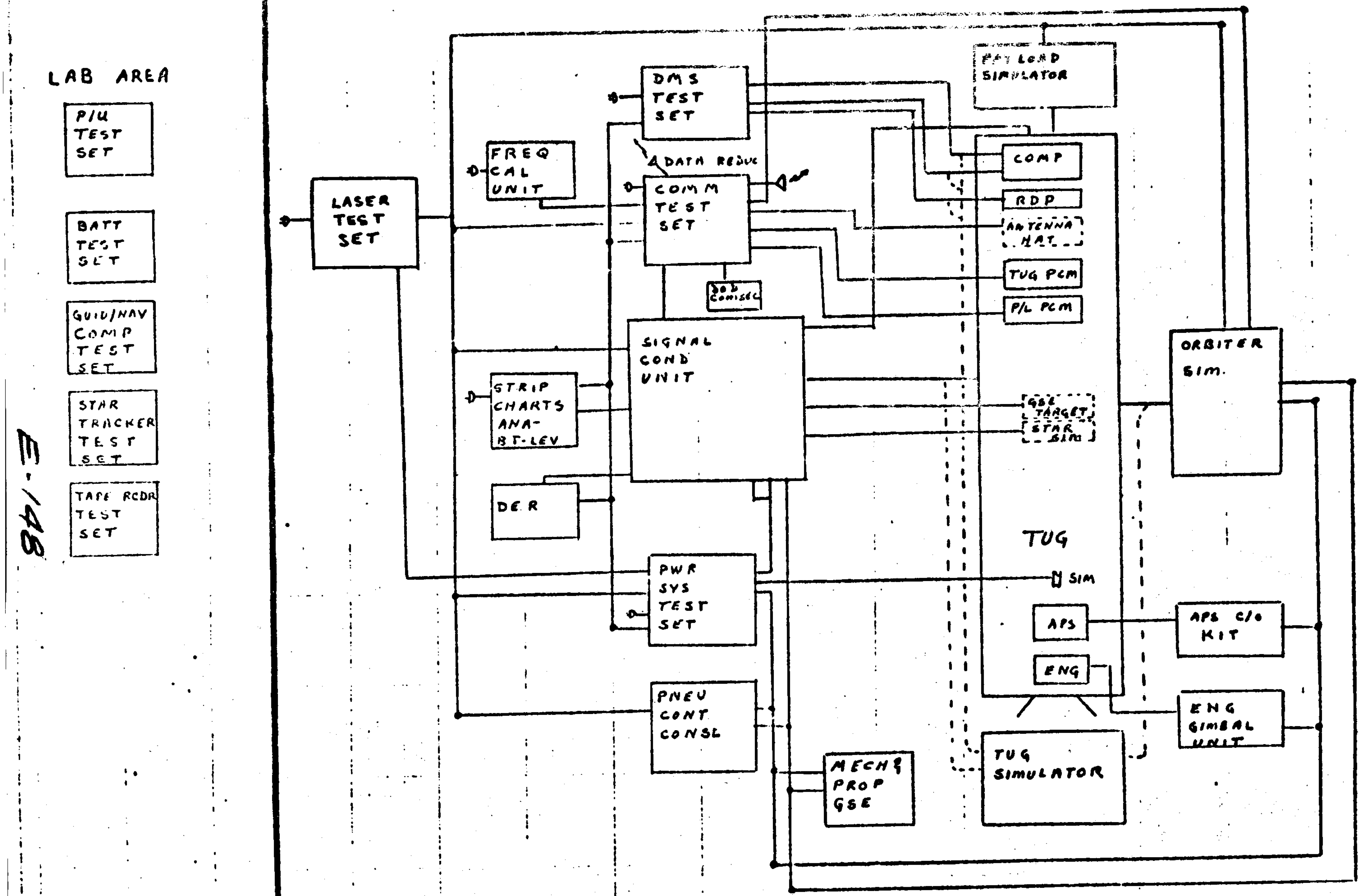
LAB AREA





FACTORY CHECKOUT

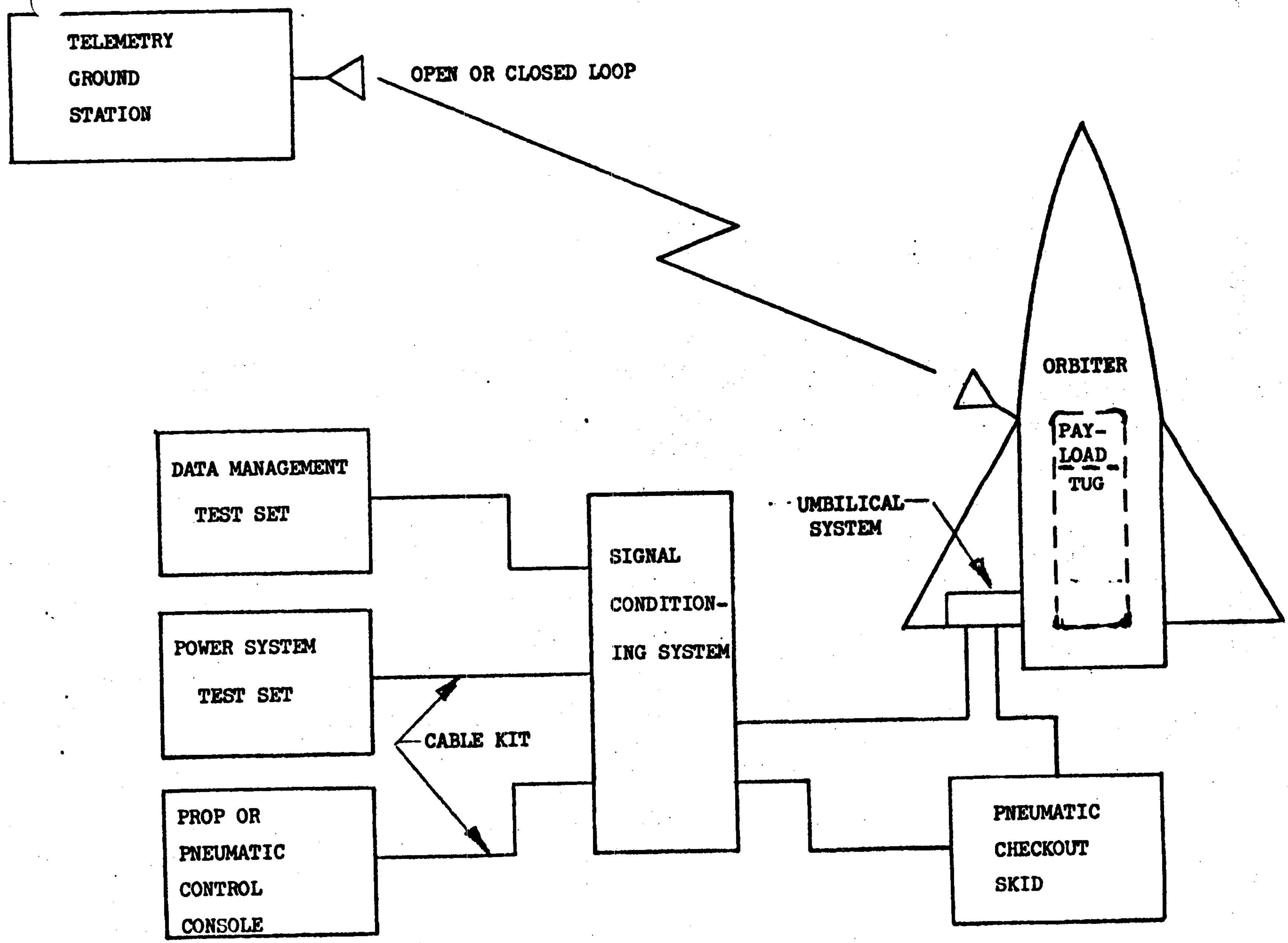
1f



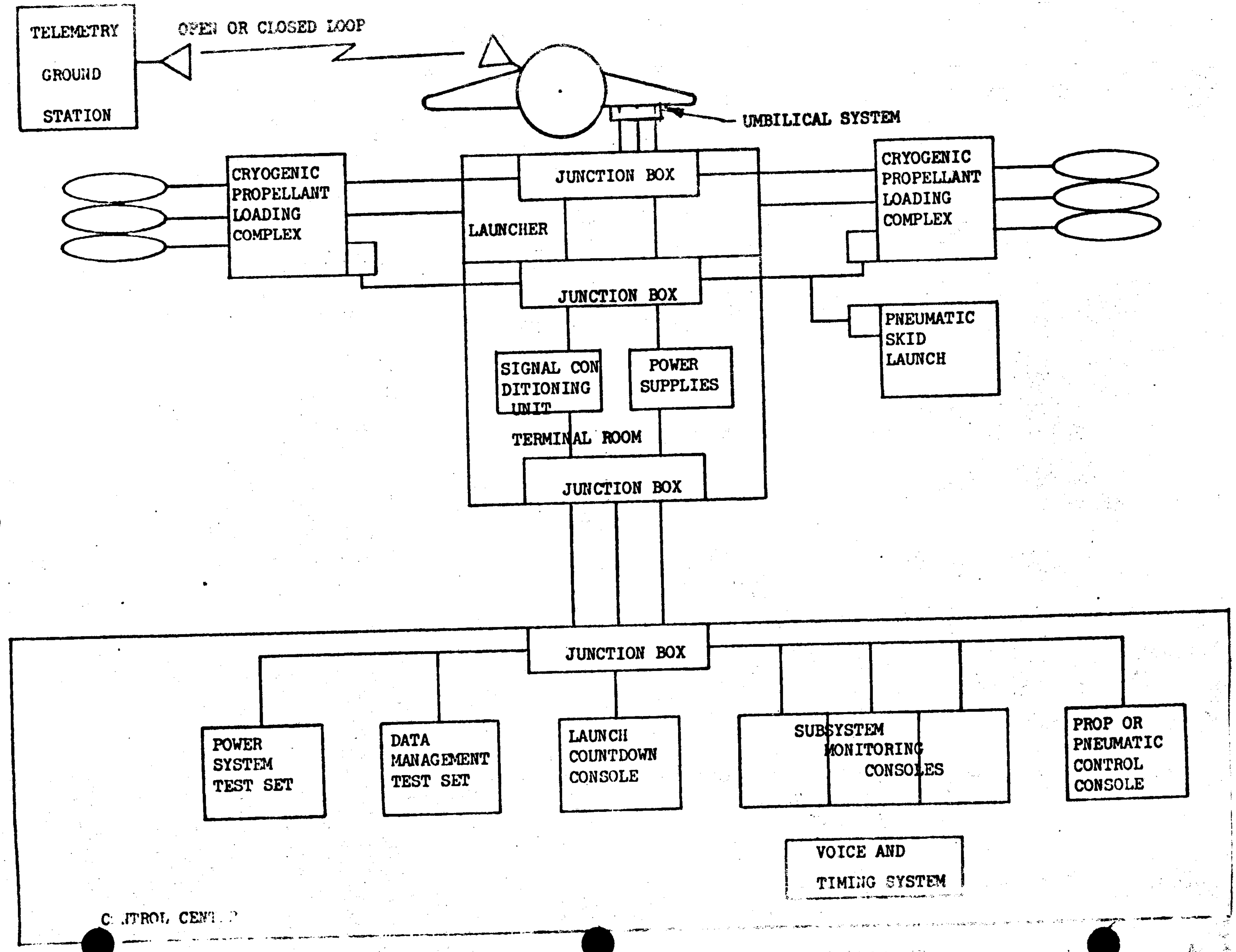
TUG PROCESSING FACILITY

12

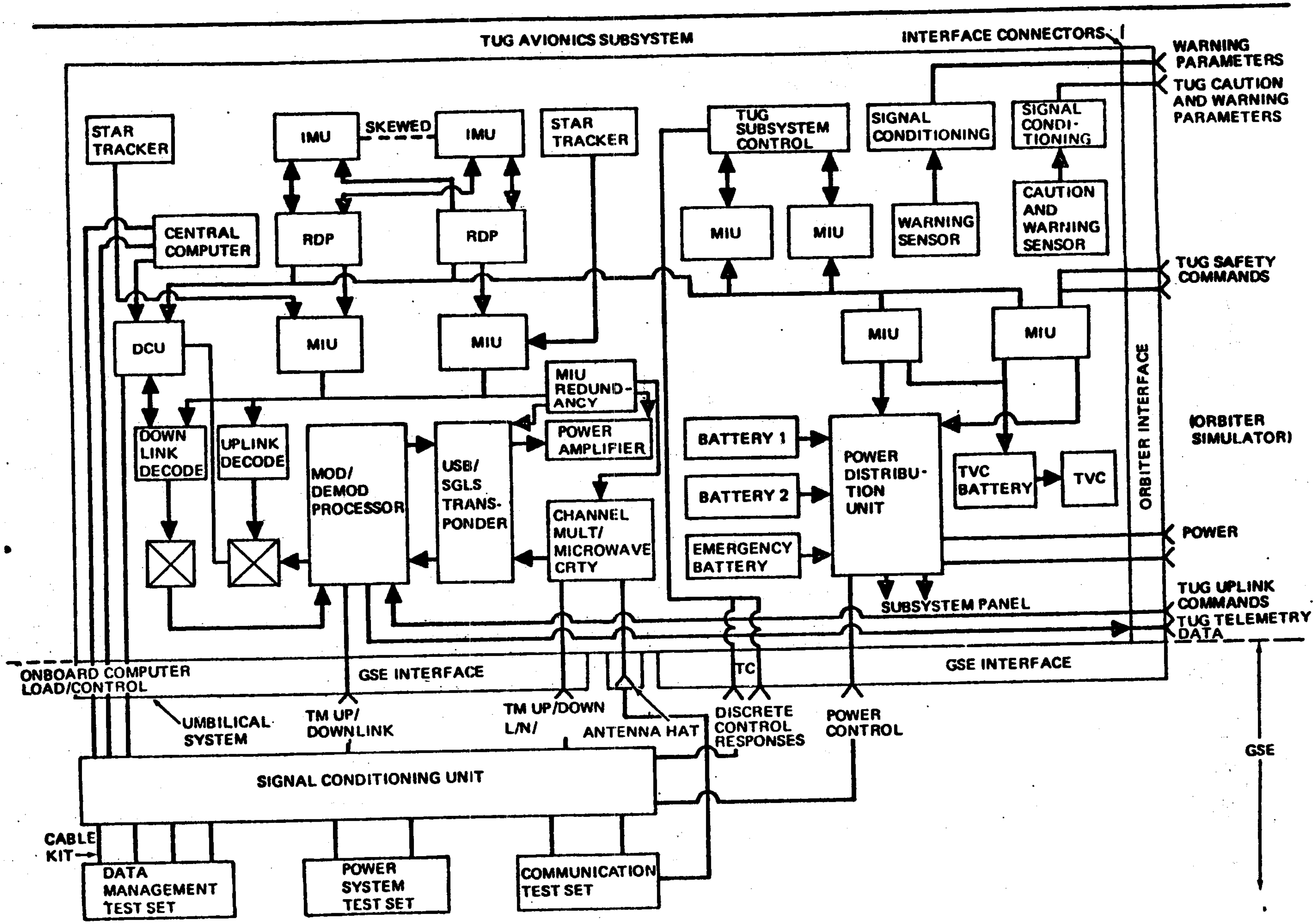
E-148



ORBITER MAINTENANCE AND CHECKOUT FACILITY


TELEMETRY
GROUND
STATION
OPEN OR CLOSED LOOP
UMBILICAL SYSTEM
CRYOGENIC PROPELLANT LOADING COMPLEX
JUNCTION BOX
LAUNCHER
JUNCTION BOX
CRYOGENIC PROPELLANT LOADING COMPLEX
PNEUMATIC SKID LAUNCH
SIGNAL CON DITIONING UNIT
POWER SUPPLIES
TERMINAL ROOM
JUNCTION BOX
JUNCTION BOX
POWER SYSTEM TEST SET
DATA MANAGEMENT TEST SET
LAUNCH COUNTDOWN CONSOLE
SUBSYSTEM MONITORING CONSOLES
PROP OR PNEUMATIC CONTROL CONSOLE
VOICE AND TIMING SYSTEM

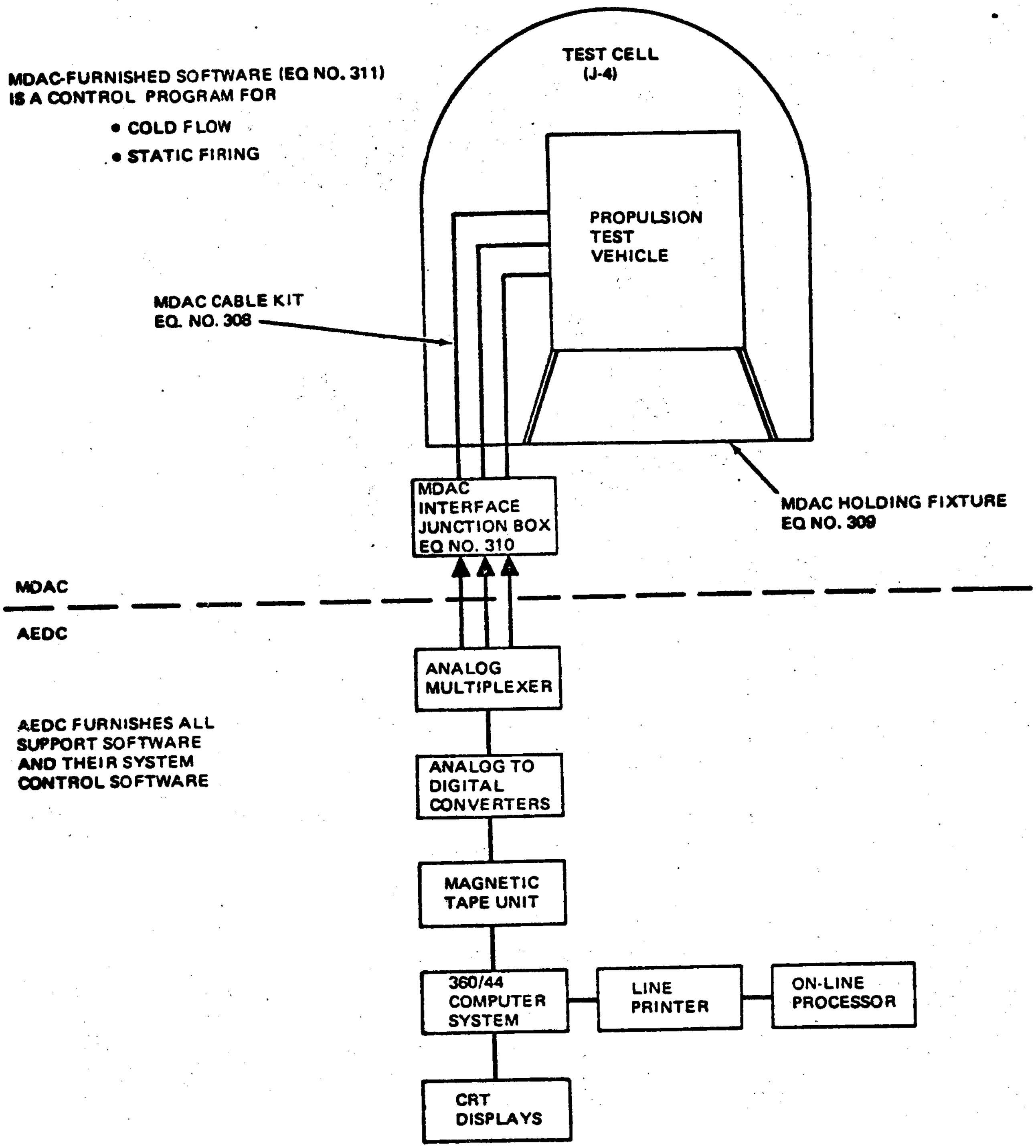
E-150



Integrated Avionics Test Unit

E-161

1j



Propulsion Test Vehicle/Ground Support Equipment Assembly

1 k

GSE DESCRIPTION SHEET

NAME: APS SERVICER EQUIPMENT NO. 113

FUNCTIONAL REQUIREMENT(S):

Provide purging, loading, and unloading of APS Bi-Propellant System

EQUIPMENT DESCRIPTION:

Modification to existing Saturn APS Servicer

Additional APS servicers are required since we have Bi propellant system

10% modification

COST PER UNIT: $ 500 (NON-RECURRING)

$ 2000 (RECURRING/YEAR)

EQUIPMENT CATEGORY:

NEW ____ MODIFIED X AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.1.7	Storable/KSC	1
	Storable/WTR	1
	Modification cost	$800.00
	4 Servicers	

TOTAL REQUIRED 2 TOTAL COST $ 4,800

GSE DESCRIPTION SHEET

NAME: CHECKOUT CABLE KIT   EQUIPMENT NO. 118

FUNCTIONAL REQUIREMENT(S):

Provides interconnects between test sets, vehicle, power, etc.

EQUIPMENT DESCRIPTION:

Consists of all cable, (power, RF, signal) required to support Tug Unique checkout in all areas. Cable network - 70 cable assemblies (80 ft) long - (35 60 pin cables; (18) 4 pin cables; (5) 39 pin cables; 7 coax cables; (5) 24 pin cables; breakout cables and general breakout box. Similar to DSV-4B-726A.

COST PER UNIT: $ 13,500 (DESIGN AND DEVELOPMENT)

$ 5,100 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW s   MODIFIED 30%   AS IS ____

1ST YEAR REQ'D ____   NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.5, 1.1.7 ALL		
1.1.8 ALL	WTR	1
1.1.9 ALL		
1.1.14		
2.3.9, 2.4.2		

TOTAL REQUIRED 1   TOTAL COST $ 5,100

GSE DESCRIPTION SHEET

NAME: COMPONENT PROTECTIVE COVERS EQUIPMENT NO. 120

FUNCTIONAL REQUIREMENT(S):

Provide prelaunch protection for vulnerable components. Removed prior to launch and returned to factory for re-use.

EQUIPMENT DESCRIPTION:

Protective covers for bellows, titanium bottles, and other components subject to ground handling damage, including G&C lens covers.

COST $ 2000 (DESIGN AND DEVELOPMENT)

$ 700 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW X MODIFIED ____ AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.4	KSC	2
1.1.20	WTR	2

TOTAL REQUIRED 4 TOTAL COST $ 2,800

E-155

GSE DESCRIPTION SHEET

NAME: COVER - SPACECRAFT EQUIPMENT NO. 122

FUNCTIONAL REQUIREMENT(S):

To provide environmental and physical protection to a SC while it is joined to the Tug on the transporter.

EQUIPMENT DESCRIPTION:

A rubber impregnated fabric cover for the SC designed to integrate with the Tug cover as a replacement for its forward section.

COST PER UNIT: $ 3,000 (DESIGN AND DEVELOPMENT)

$ 500 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW X MODIFIED ____ AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE 0

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.4	KSC	2
1.1.2.1	WTR	2
1.1.2.6		
2.3.6		
2.4.8		

TOTAL REQUIRED 4 TOTAL COST $ 2,000

FORM X60-999-3 (10-62)

SYM

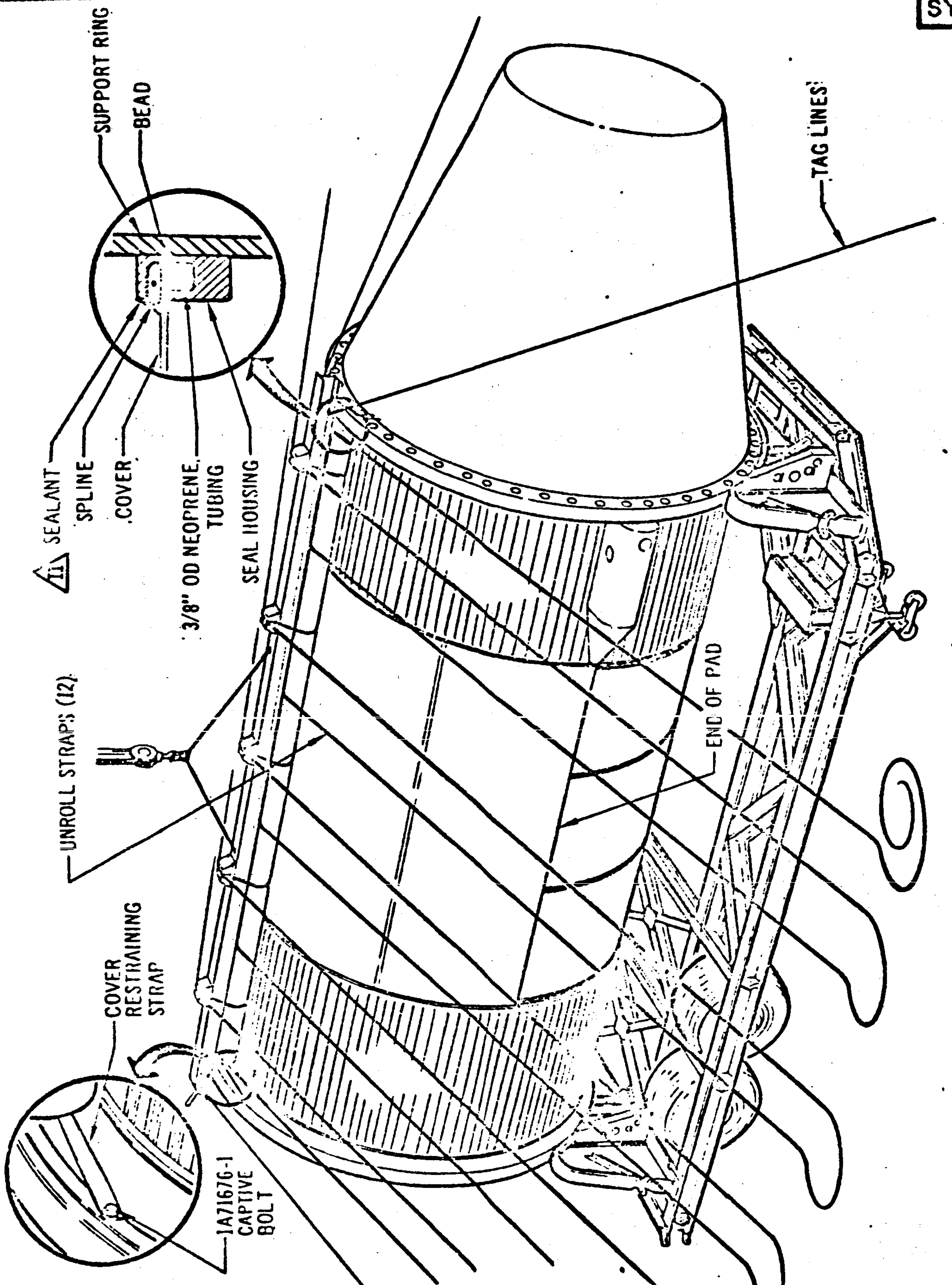


FIGURE 6
CENTER COVER INSTALLATION

CODE IDENT NO.	SIZE	
18355	A	COVERS - SPACECRAFT/TUG

E-157

SHEET

GSE DESCRIPTION SHEET

NAME: Cover-Tug EQUIPMENT NO. 123

FUNCTIONAL REQUIREMENT(S):

To provide environmental and physical protection to the Tug during transport protection to the Tug during transport and storage in the horizontal position.

EQUIPMENT DESCRIPTION:

A rubber impregnated nylon fabric cover fabricated to V shape in three segments which are assembled on the Tug by laced and zippered closures.

COST PER UNIT: $ 3500 (DESIGN AND DEVELOPMENT)

$ 800 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW X MODIFIED ____ AS IS ____

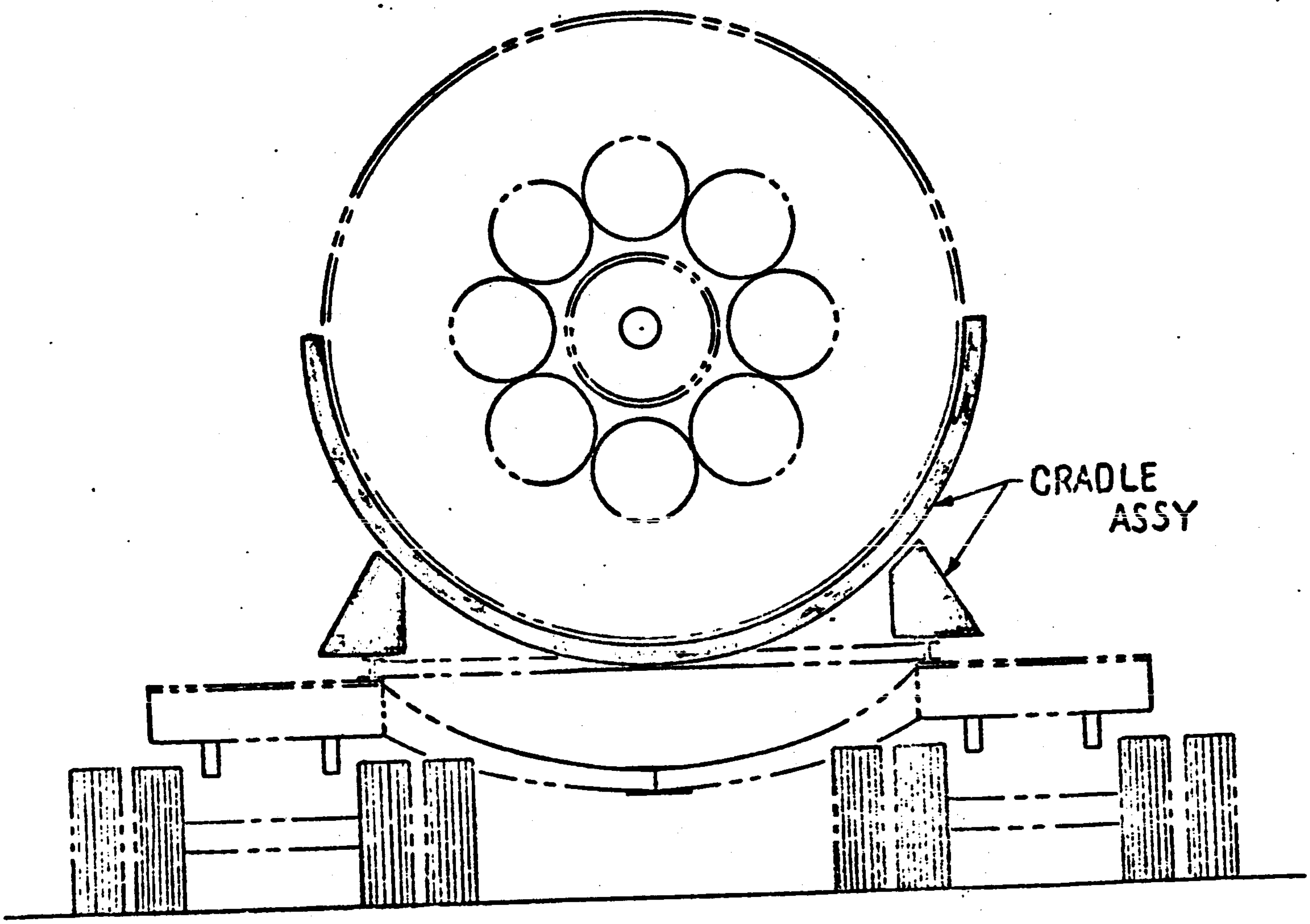
1ST YEAR REQ'D ____ NUMBER AVAILABLE 0

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.2.1	KSC	2
1.1.22	WTR	2
1.1.24		

TOTAL REQUIRED 4 TOTAL COST $ 3,200

E-158



CRADLE ASSY

GSE DESCRIPTION SHEET

NAME: CRADLES

EQUIPMENT NO. 124

FUNCTIONAL REQUIREMENT(S):

To provide a means to support and restrain the Tug on its transporter.

EQUIPMENT DESCRIPTION:

An intermediate steel structure to fit between and attach to the Tug and transporter.

COST PER UNIT: $ 100,000 (DESIGN AND DEVELOPMENT)

$ 65,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW X MODIFIED ____ AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE 0

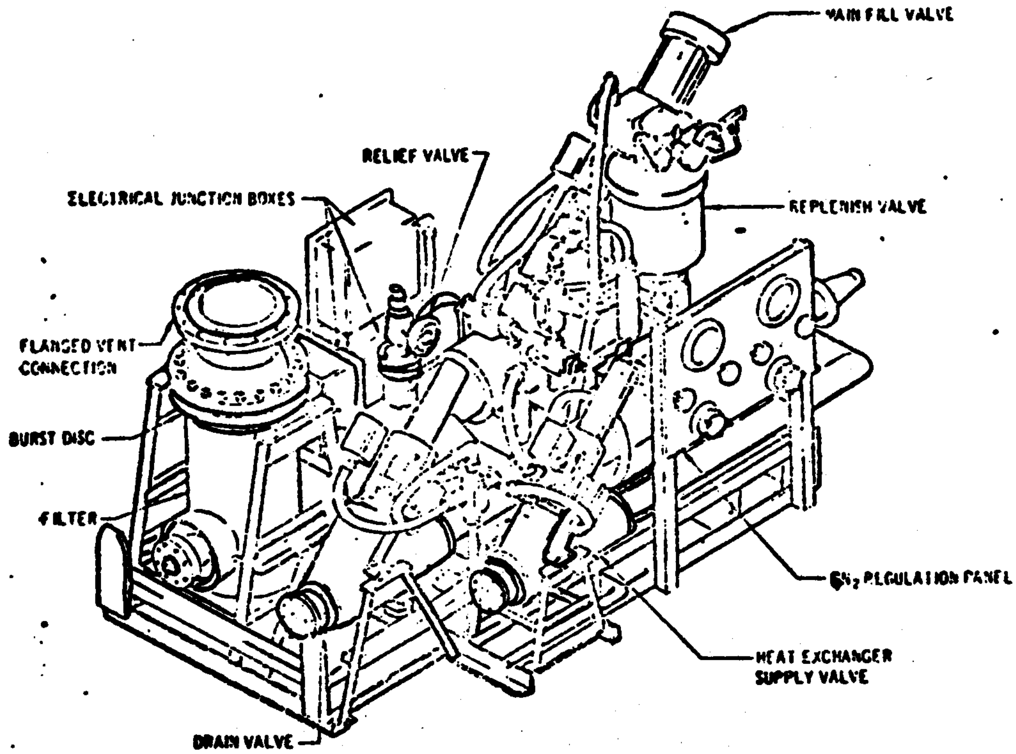
EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.20	KSC	2
	WTR	2

TOTAL REQUIRED 4

TOTAL COST $ 260,000

E-160



CRYOGENIC PROPELLANT LOADING COMPLEX

GSE DESCRIPTION SHEET

NAME: CRYO. PROPELLANT LOADING COMPLEX EQUIPMENT NO. 125

FUNCTIONAL REQUIREMENT(S):

Provide for transfer and control of LO_2 and LH_2 from facility to vehicle umbilical.

EQUIPMENT DESCRIPTION:

LH_2 and LO_2 loading complex utilizing hardware from Sacramento Test Center and KSC where possible. (Control valves, umbilicals, etc.) (Utilize Shuttle topping system.) Same as DSV-4B-331 and -332.

COST $ 40,000 (DESIGN AND DEVELOPMENT)

$ 20,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED X AS IS X GFE facilities at ETR

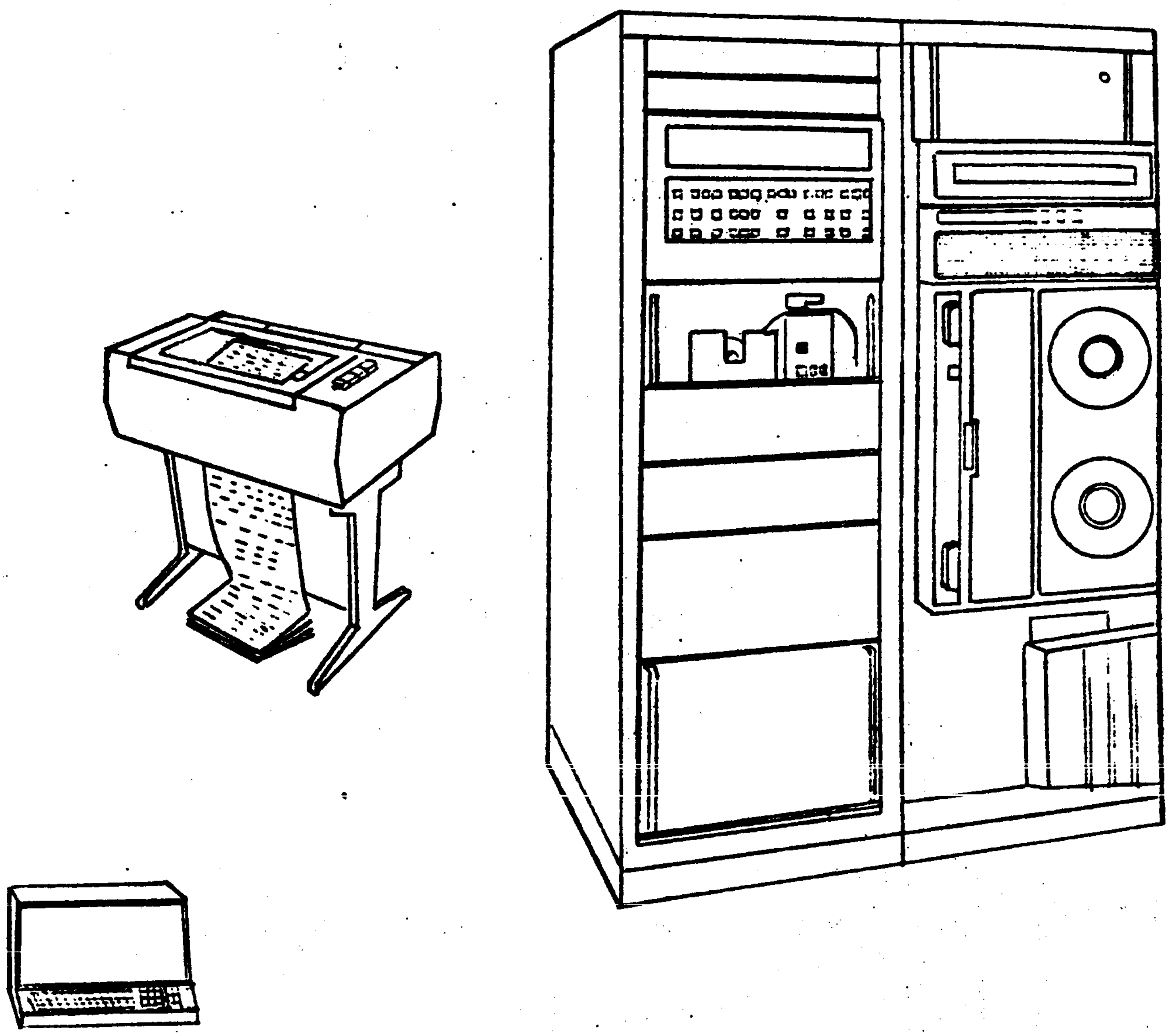
1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.4.3	KSC	
	WTR	1

TOTAL REQUIRED 1 TOTAL COST $ 20,000

E-162



DATA MANAGEMENT TEST SET

GSE DESCRIPTION SHEET

NAME: DATA MANAGEMENT SYSTEM T/S (DMST/S) EQUIPMENT NO. 127

FUNCTIONAL REQUIREMENT(S):

Controls operation of DMS computer and monitors computer status, initials program loading and verification, performs functional verification of DMS command and control functions, interface with other T/S for dedicated displays, verify selected subsystem parameters as program.

EQUIPMENT DESCRIPTION:

Portable console interfacing with computer for program verification and DMS memory dump C/O, paper tape memory loader, tape reader, DMS computer control and status panel, dedicated display panel for DMS function and programmable display for other subsystem functions (GNC, Comm, Power, and Prop.) - CRT

COST PER UNIT: $ 1,033,000 (NON-RECURRING)

$ 412,000 (RECURRING/YEAR)

EQUIPMENT CATEGORY:

NEW X MODIFIED ____ AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.5, 1.1.7 ALL		
1.1.8 ALL, 1.1.9 ALL		
2.3.9, 2.4.3		
	Launch Pad/WTR	1

TOTAL REQUIRED 1 TOTAL COST $ 412,000

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: FM TRANSMITTER COMPONENT TEST SET EQUIPMENT NO. 135

FUNCTIONAL REQUIREMENT(S):

Provides adjustment, calibration, and functional analyses for FM transmitters and RF power amplifier in stage.

EQUIPMENT DESCRIPTION:

Similar to DSV-4B-252

COST $ 30,000 (DESIGN AND DEVELOPMENT)

$ 100,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

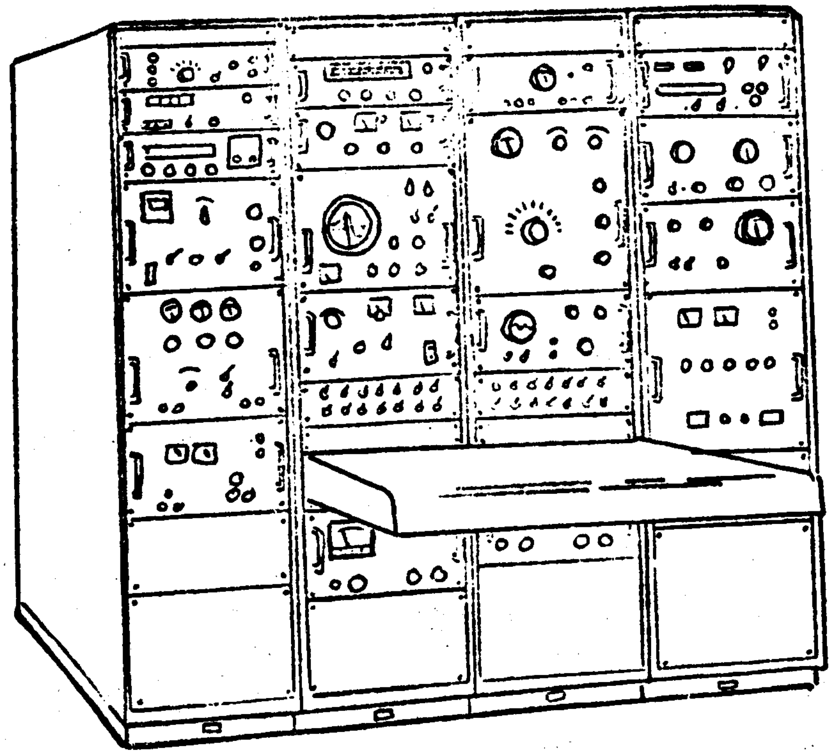
NEW ________ MODIFIED ________ AS IS 100%

1ST YEAR REQ'D ________ NUMBER AVAILABLE ________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
	Factory	1

TOTAL REQUIRED 1 TOTAL COST $ 130,000



FM TRANSMITTER COMPONENT TEST SET

CONFIGURATION OPTION ______

GSE DESCRIPTION SHEET

NAME: FREQUENCY CALIBRATION UNIT RACK ASSEMBLY EQUIPMENT NO. 136

FUNCTIONAL REQUIREMENT(S):

Measures frequency of TM signals received by ground stations. Contains frequency standard device to measure and display TM signals. Calibrates TM signals.

EQUIPMENT DESCRIPTION:

Similar to DSV-4B-128

COST $ 10,000 (DESIGN AND DEVELOPMENT)

$ 84,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

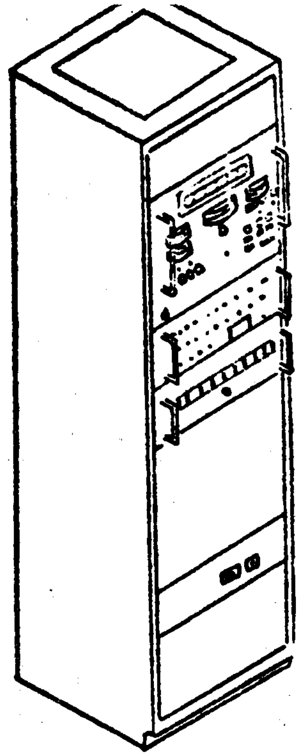
NEW ______ MODIFIED ______ AS IS ______

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

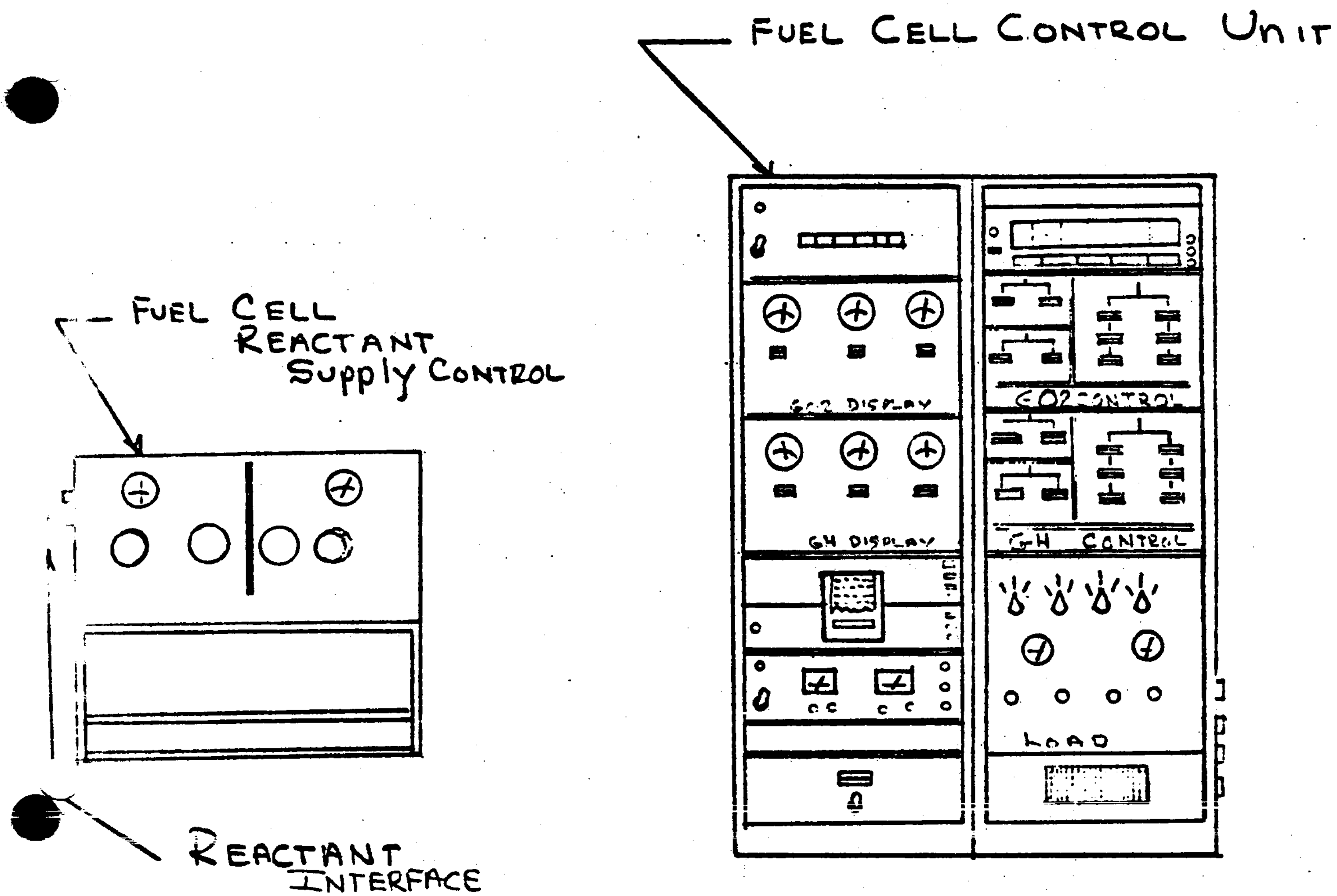
EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
	Factory	1

TOTAL REQUIRED 1 TOTAL COST $ 94,000



FREQUENCY CALIBRATION UNIT



FUEL CELL CHECKOUT KIT

CONFIGURATION OPTION 3 F

GSE DESCRIPTION SHEET

NAME: FUEL CELL CHECKOUT KIT EQUIPMENT NO. 137

FUNCTIONAL REQUIREMENT(S):

Supply reactant gases to fuel cell battery (FCB), provide test loads for FCB, provide signals to control FCB operation, measure response, remove heat from FCB, via coolant passages and make diagnostic measurements of FCB.

EQUIPMENT DESCRIPTION:

Composed of work platform; fluid connections for gaseous oxygen and hydrogen, pressure regulators, electronic equipment racks, test cables and connectors. Electronic rack consists of power supply, load bank, and control panel assembly with switches, meters, line printer, sequencer, digital voltmeter, and associated circuitry.

COST PER UNIT: $ 180,000 (NON-RECURRING)

$ 75,000 (RECURRING/YEAR)

EQUIPMENT CATEGORY:

NEW X MODIFIED ____ AS IS ____

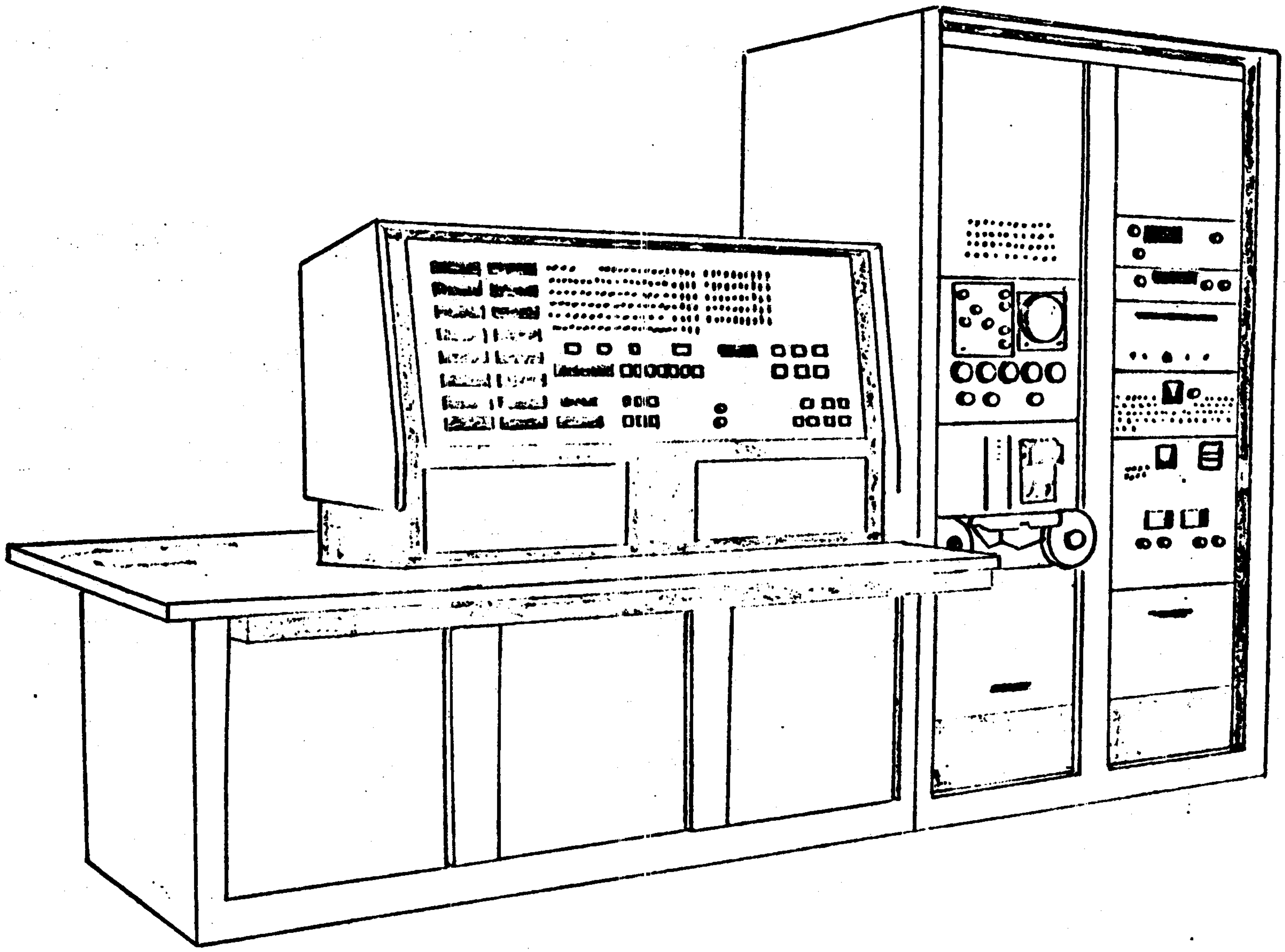
1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.4.3(a)	KSC (Safing Area)	1
	WTR (Safing Area)	1
	Factory	1

TOTAL REQUIRED 3 TOTAL COST $ 405,000

E-170



GUIDANCE AND NAVIGATION TEST SET

GSE DESCRIPTION SHEET

NAME: GUIDANCE AND NAVIGATION TEST SET EQUIPMENT NO. 142

FUNCTIONAL REQUIREMENT(S):

Monitors and verifies checkout of IMU and GC. It provides calibration, alignment and simulation of navigation programs. Capable of simulations of all flight programs.

EQUIPMENT DESCRIPTION:

Rate table and associated electronic bays which include display panel, control panel, oscilloscope, universal counter, Digital voltmeter, interface (DIU) assy, power supplies, digital printer paper tape punch, test point control panel, downlink display panel, etc.

COST $ 150,000 (DESIGN AND DEVELOPMENT)

$ 89,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW X MODIFIED ____ AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.13	KSC	1
	WTR	1
	Factory	1

TOTAL REQUIRED 3 TOTAL COST $ 417,000

E-172

GSE DESCRIPTION SHEET

NAME: GUIDANCE AND NAVIGATION SYSTEM CHECKOUT KIT EQUIPMENT NO. 143

FUNCTIONAL REQUIREMENT(S):

Interfaces between Tug IMU and GC and the laboratory test equipment. Also provides mounting of IMU to rate table.

EQUIPMENT DESCRIPTION:

Consists of IMU holding fixture and cables.

COST $ 10,000 (DESIGN AND DEVELOPMENT)

$ 5,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW x MODIFIED ___ AS IS ___

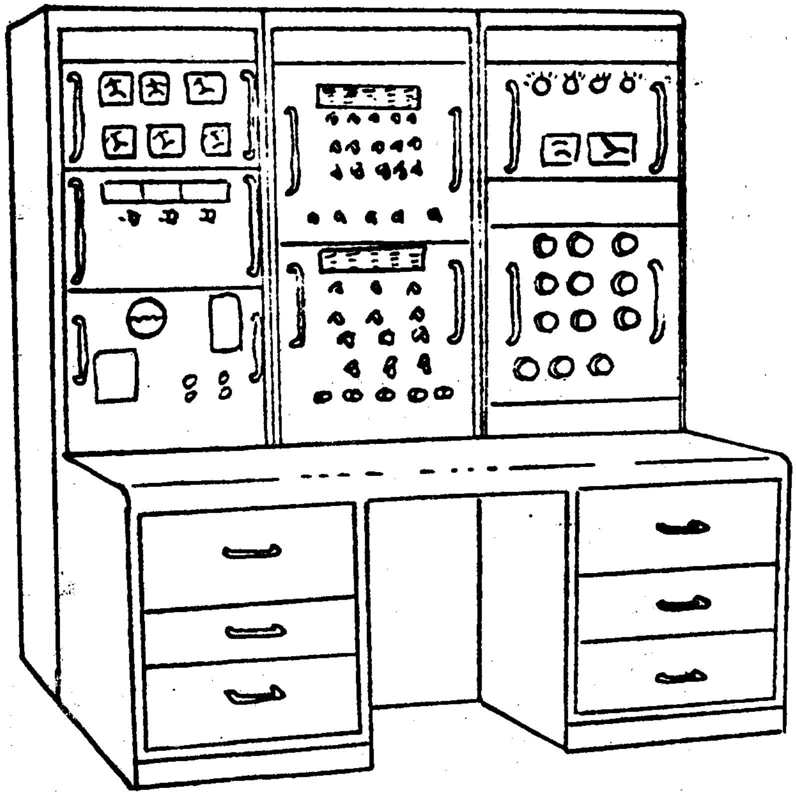
1ST YEAR REQ'D ___ NUMBER AVAILABLE ___

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.13	KSC	1
	WTR	1
	Factory	1

TOTAL REQUIRED 3 TOTAL COST $ 25,000

E-173



LASER RADAR CHECKOUT AND ANALYSIS KIT

GSE DESCRIPTION SHEET

NAME: LASER RADAR CHECKOUT & ANALYSIS KIT EQUIPMENT NO. 144

FUNCTIONAL REQUIREMENT(S):

Test coolant system, check alignment, check range and RCVR, check modulation, measure power and energy, and measure servo response

EQUIPMENT DESCRIPTION:

3 bay console, beam splitter, dichroic lens, optical source target, and test analysis test set. This kit consists of radimeter, interferometer, modulation test box, transfer meter, power meter oscilloscope, and etc.

COST $ 120,000 (DESIGN AND DEVELOPMENT)

$ 70,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

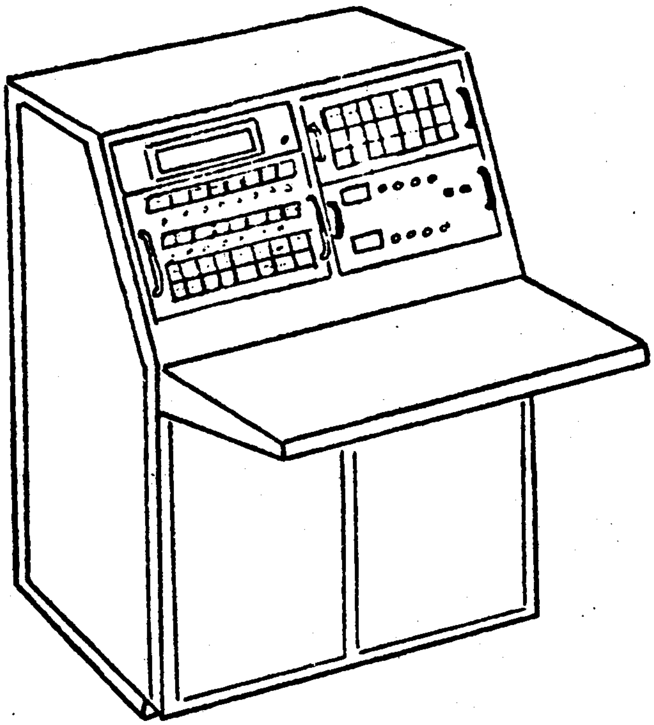
NEW X MODIFIED ____ AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.9.9	KSC	1
	WTR	1
	Factory	1

TOTAL REQUIRED 3 TOTAL COST $ 330,000



LAUNCH COUNTDOWN CONSOLE

GSE DESCRIPTION SHEET

NAME: LAUNCH COUNT DOWN CONSOLE EQUIPMENT NO. 145

FUNCTIONAL REQUIREMENT(S):

Controls and monitors launch checkout and count down of Tug vehicle.

EQUIPMENT DESCRIPTION:

Console with intercom and count down clock, status indicators, alpha numerical display and associated circuitry.

COST $ 30,000 (DESIGN AND DEVELOPMENT)

$ 20,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW X MODIFIED ____ AS IS X GFE at ETR

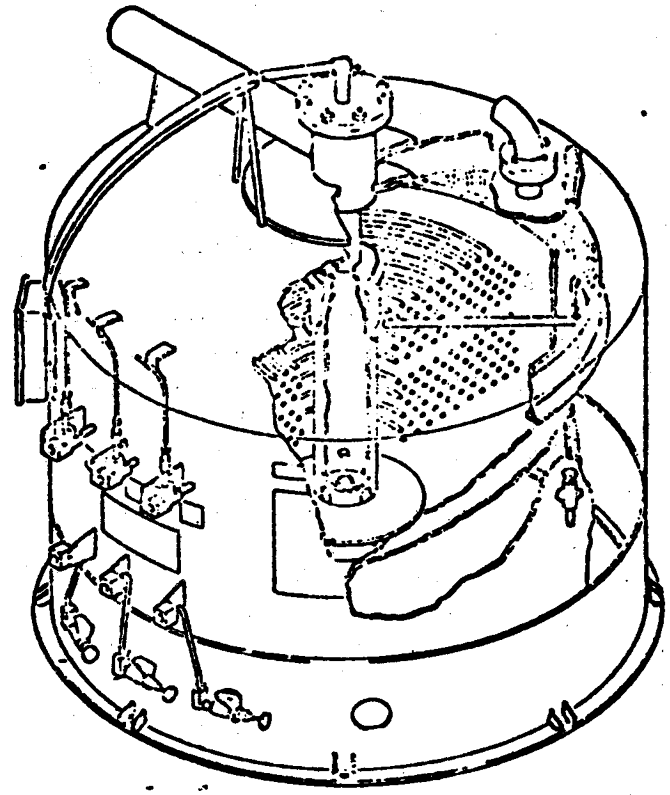
1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.4.3		
2.4.4	WTR	1

TOTAL REQUIRED 1 TOTAL COST $ 20,000

E-177



LH_2 - HEAT EXCHANGER

GSE DESCRIPTION SHEET

NAME: LH_2-He HEAT EXCHANGER EQUIPMENT NO. 147

FUNCTIONAL REQUIREMENT(S):

Provide prechilling of helium used for APS tank pressurization or main propellant tank pressurization

EQUIPMENT DESCRIPTION:

LH_2-He heat exchanger utilizing hardware from Sacramento Test Center and KSC where possible.

COST: $ 0 (DESIGN AND DEVELOPMENT)

$ 20,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED X AS IS ______

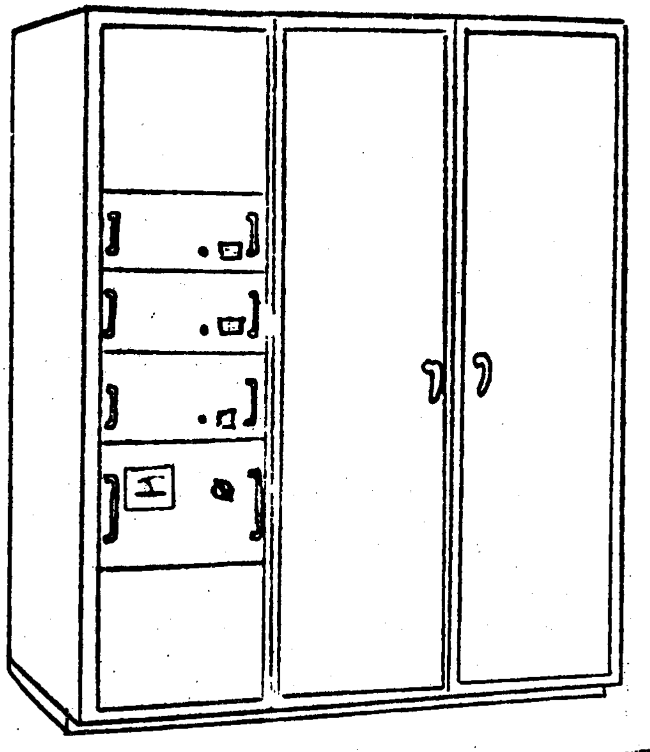
1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.8.2		
1.1.9.7	WTR	1

TOTAL REQUIRED 1 TOTAL COST $ 20,000

E-179



SIGNAL CONDITIONING UNIT

CONFIGURATION OPTION 3F

GSE DESCRIPTION SHEET

NAME: SIGNAL CONDITIONING UNIT EQUIPMENT NO. 148

FUNCTIONAL REQUIREMENT(S):

Interfaces between Tug vehicle and GSE for signal and power conditioning, and distribution

EQUIPMENT DESCRIPTION:

Consists of a 3 bay console which contains junction box, (1) 1032 point patch panel assembly, (10) isolation amplifiers, (1) 4 row relay-plane, (10) buffer amplifiers, (1) logic power supply, and (20) connectors and associated wiring. (Similar to DSV-4B-133).

COST $ 300,000 (DESIGN AND DEVELOPMENT)

$ 120,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW x MODIFIED ____ AS IS ____

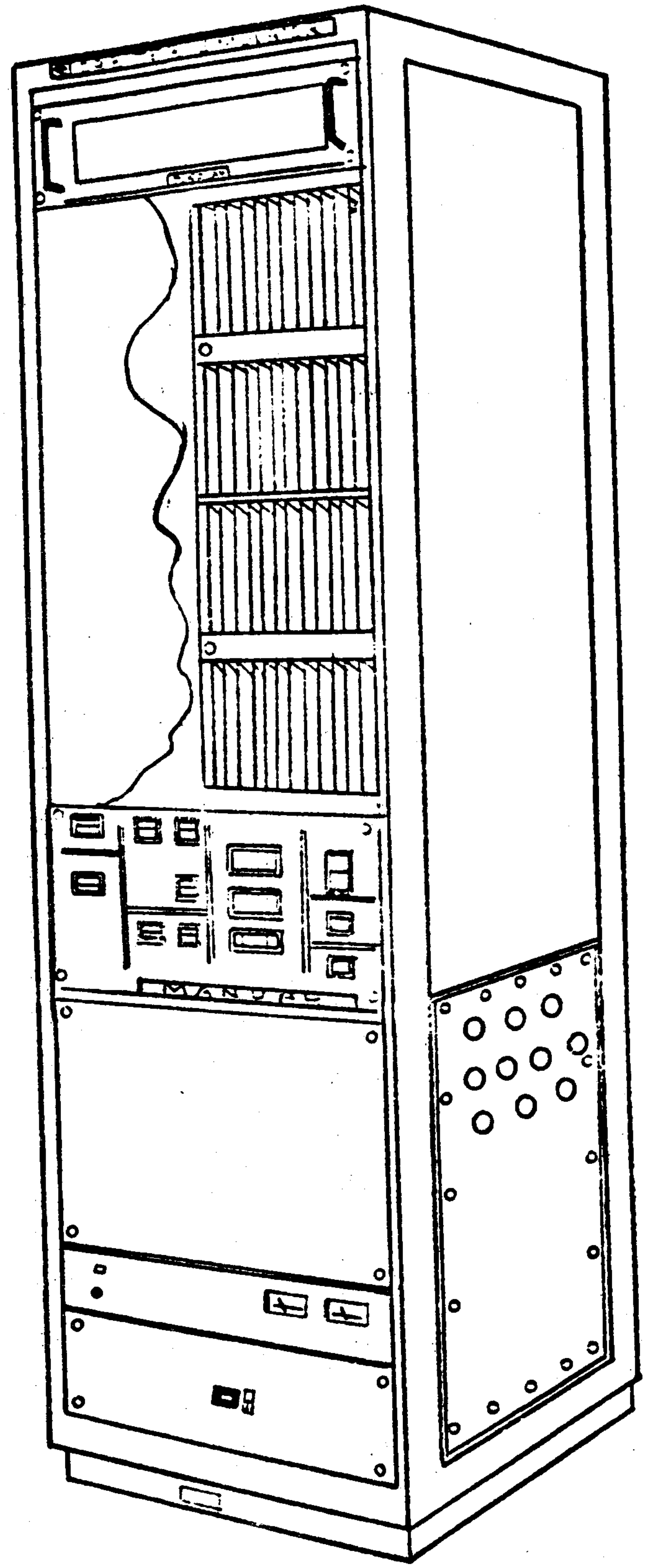
1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.5		
1.1.7 ALL		
1.1.8 ALL		
2.3.9		
2.4.3	Launch Pad/WTR	1

TOTAL REQUIRED 1 TOTAL COST $ 120,000

E-181



ORBITER SIMULATOR

CONFIGURATION OPTION 3F

GSE DESCRIPTION SHEET

NAME: ORBITER SIMULATOR EQUIPMENT NO. 149

FUNCTIONAL REQUIREMENT(S):

Functionally simulates orbiter/Tug interfaces for verification of electrical parameters

EQUIPMENT DESCRIPTION:

Portable test set containing encoder, decoder and load test circuits.

Contains switches and indicator lights

10% modification due to avionics changes.

COST $ 400,000 (DESIGN AND DEVELOPMENT)

$ 100,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

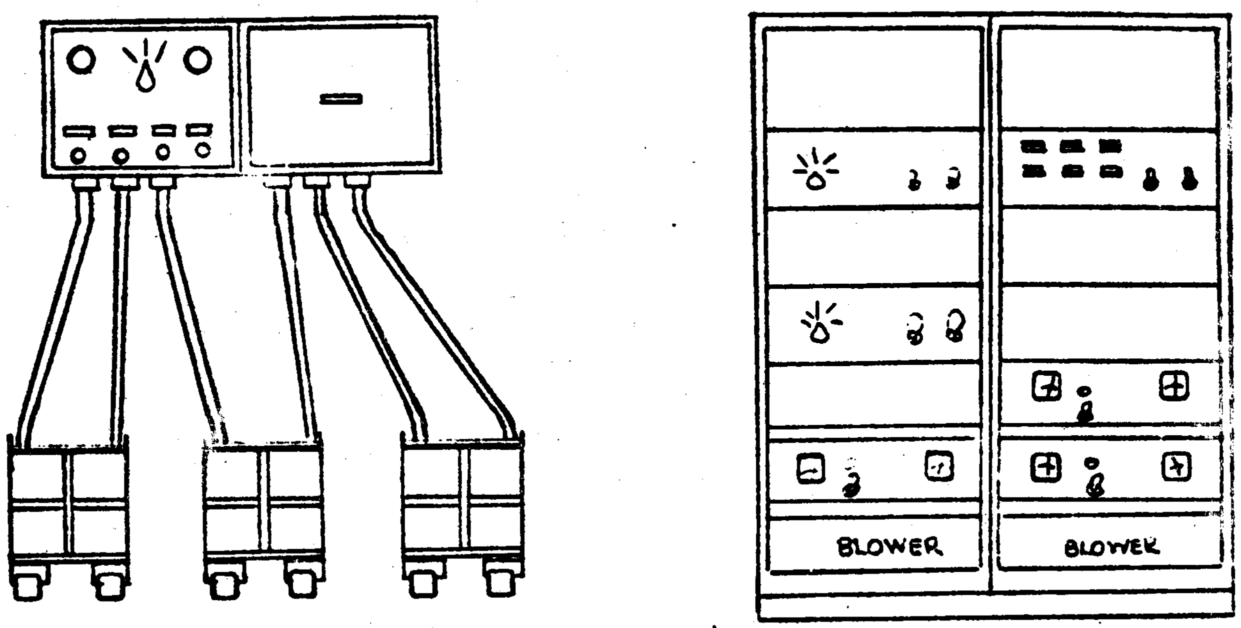
NEW ____ MODIFIED X AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.7.9	TPF/KSC	1 x
1.1.8.9	PPF/WTR	1 x
1.1.9.9	Factory	1 x

TOTAL REQUIRED 3 TOTAL COST $ 30,000



Power System Test Set

CONFIGURATION OPTION 3F

GSE DESCRIPTION SHEET

NAME: POWER SYSTEM T/S (PSTS) EQUIPMENT NO. 155

FUNCTIONAL REQUIREMENT(S):

Provide means to load fuel cells and vehicle power distribution system. Provide ground power sources for vehicle and GSE. Provide emergency power in event facility power malfunction.

EQUIPMENT DESCRIPTION:

Two bay rack of electrical equipment containing two independent programmable power supplies for vehicle power, one programmable power supply for GSE power, and programmable loads for vehicle power system C/O, a backup battery unit is provided for emergency power.

COST PER UNIT: $ 134,000 (NON-RECURRING)

$ 48,000 (RECURRING/YEAR)

EQUIPMENT CATEGORY:

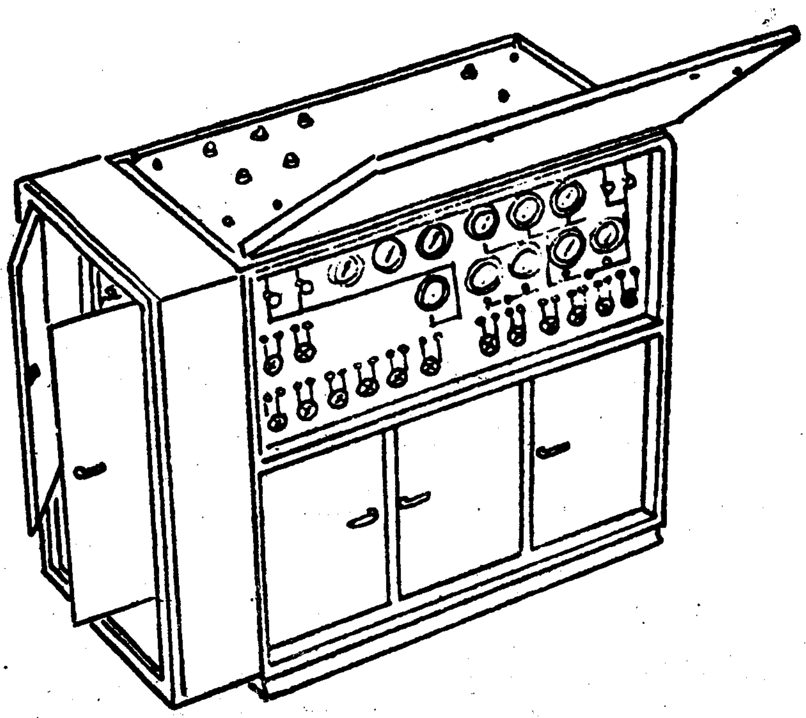
NEW X MODIFIED ______ AS IS ______

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.5, 1.1.7 ALL		
1.1.8 ALL 1.1.9 ALL		
2.3.9, 2.4.2		
2.4.3		
	Launch Pad/WTR	1

TOTAL REQUIRED 1 TOTAL COST $ 48,000



PROPULSION PNEUMATIC CONSOLE
(LAUNCH)

GSE DESCRIPTION SHEET

NAME: PNEUMATIC SKID LAUNCH EQUIPMENT NO. 162

FUNCTIONAL REQUIREMENT(S):

Provide regulated gas supplies to vehicle for pressurization of pneumatic and propellant systems for pad checkout and launch.

EQUIPMENT DESCRIPTION:

Pneumatic console such as DSV-4B-432A modified for special Tug requirements.

COST $ 50,000 (DESIGN AND DEVELOPMENT)

$ 450,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

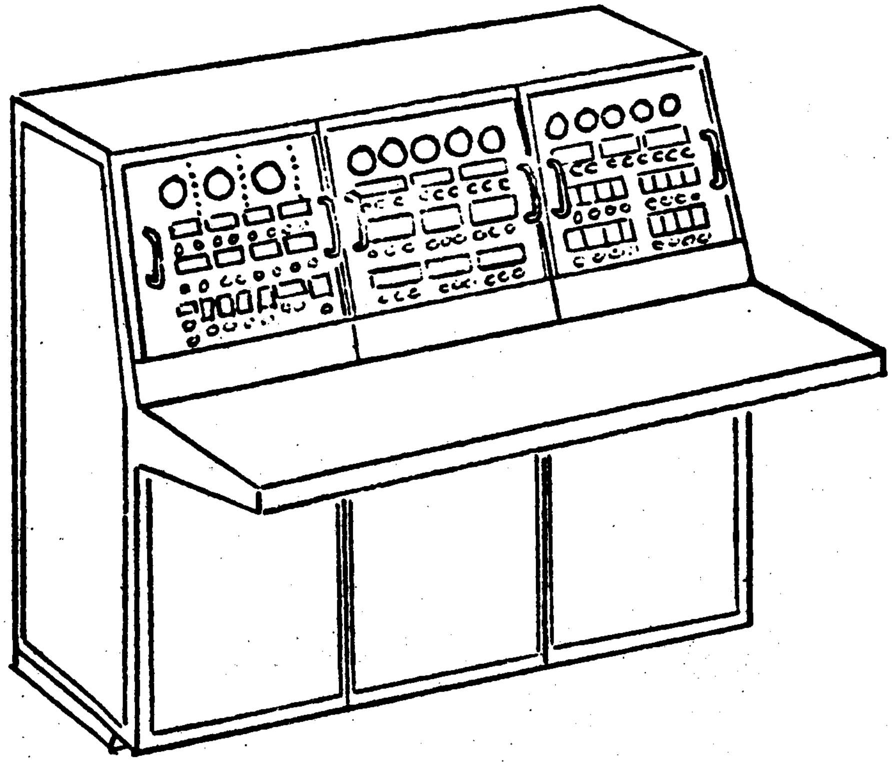
NEW X WTR MODIFIED ______ AS IS X GFE ETR

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.4.2	Launch Area/KSC	
2.4.3	Launch Area/WTR	1

TOTAL REQUIRED 1 TOTAL COST $ 450,000



PROPELLANT OR PNEUMATIC CONTROL CONSOLE

GSE DESCRIPTION SHEET

NAME: PROPELLANT OR PNEUMATIC CONTROL CONSOLE EQUIPMENT NO. 163

FUNCTIONAL REQUIREMENT(S):

Controls and pneumatic regulated gas supplies for vehicle pressurization of pneumatics and propellant systems. Used for checkout, purge, and pressure checks and loading of pneumatics into Tug vehicle. Monitors propellant loading and unloading. Capable of semi-automatic or manual loading of propellants.

EQUIPMENT DESCRIPTION:

Three bay console with intercom, light and indicators, switches, and alpha numerical display, and associated circuitry. (Similar to DSV-4B-233.)

COST PER UNIT: $ 339,000 (NON-RECURRING)

$ 334,000 (RECURRING/YEAR)

EQUIPMENT CATEGORY:

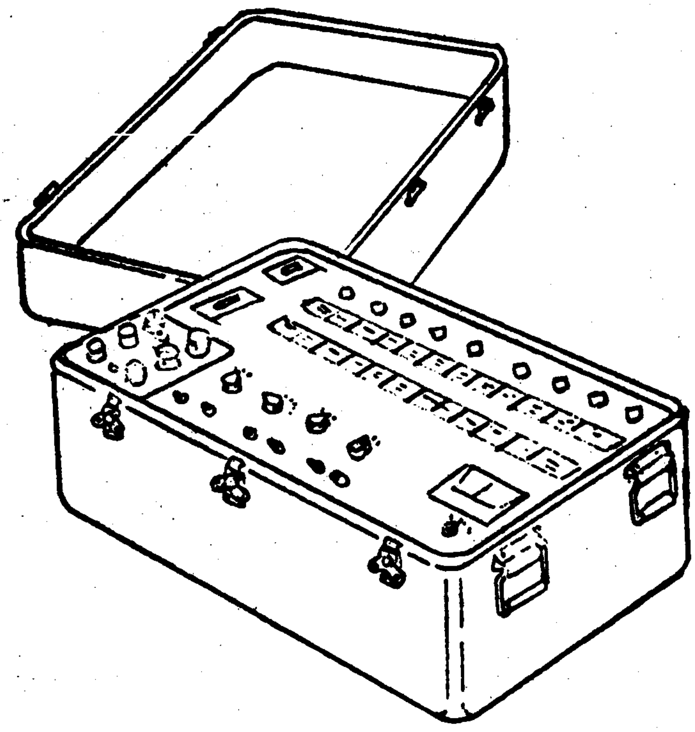
NEW X WTR MODIFIED ______ AS IS ______ ETR

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.7.1, -.4		
1.1.7.6 - 9	Launch Pad/WTR	1
1.1.8 ALL		
1.1.9 ALL		
2.4.2		

TOTAL REQUIRED 1 TOTAL COST $ 334,000



SPACECRAFT SIMULATOR

CONFIGURATION OPTION 3F

GSE DESCRIPTION SHEET

NAME: SPACECRAFT SIMULATOR EQUIPMENT NO. 168

FUNCTIONAL REQUIREMENT(S):

Functionally simulates Tug/Spacecraft interface for verification of electrical parameters.

EQUIPMENT DESCRIPTION:

Portable tester containing encoder, decoder and load test circuits. 10% modification due to Avionic System changes.

COST $ 150,000 (DESIGN AND DEVELOPMENT)

$ 50,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

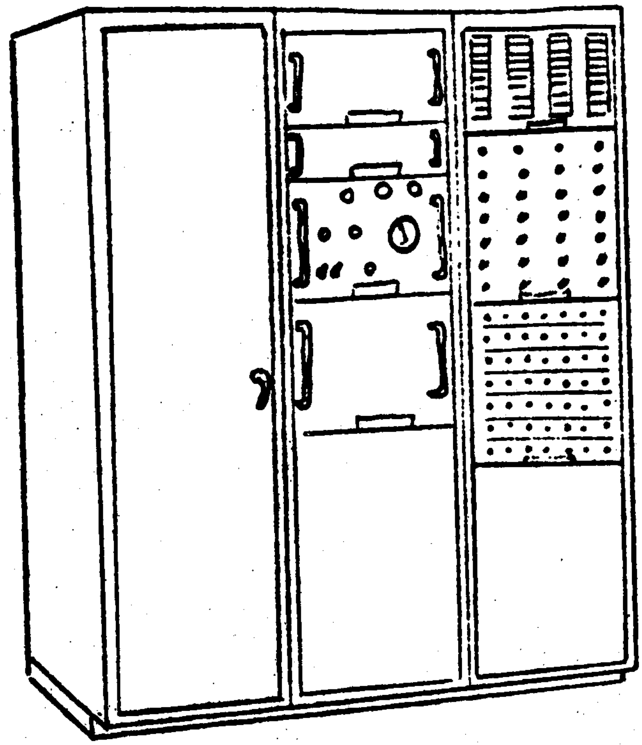
NEW ____ MODIFIED X AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.7.9	TPF/KSC	1 x
1.1.8.9	PPF/WTR	1 x
/1.1.9.9	Factory	1 x

TOTAL REQUIRED 3 TOTAL COST $ 15,000



SPACE TUG SIMULATOR

CONFIGURATION OPTION 3F

GSE DESCRIPTION SHEET

NAME: SPACE TUG SIMULATOR **EQUIPMENT NO.** 169

FUNCTIONAL REQUIREMENT(S):

Functionally simulates Tug electrical parameters for verification of GSE, payloads and Shuttle interfaces.

EQUIPMENT DESCRIPTION:

3 Bay console ~~interfacing with computer complex containing logic cards, encoder, decoder, and load test, test point assembly, indicator panels, logic power supply, path panel (similar to DSV-4B-132).~~

10% modification due to Avionics System changes.

COST $ ~~400,000~~ (DESIGN AND DEVELOPMENT)

$ ~~100,000~~ (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED x AS IS ______

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.7.9	TPF/KSC	1 x
~~1.1.8.9~~		
~~1.1.9.9~~	PPF/WTR	1 x
	Factory	1 x

TOTAL REQUIRED 3 TOTAL COST $ 30,000

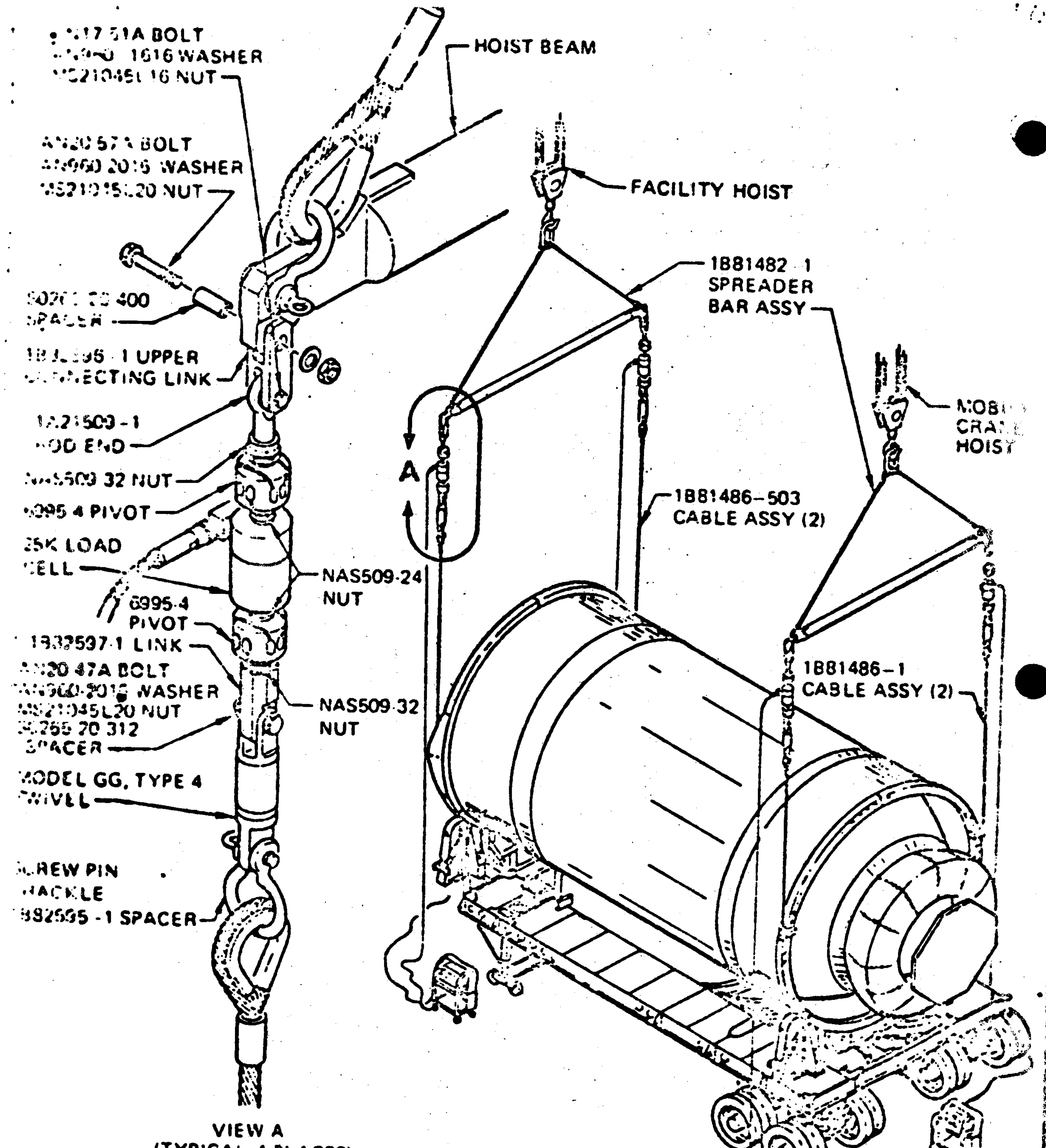


FIGURE 1.

MCDONNELL DOUGLAS ASTRONAUTICS CO. WESTERN DIVISION HUNTINGTON BEACH, CALIFORNIA	SIZE	CODE IDENT NO.	DRAWING NO.
	A	18355	STAGE WEIGHT & BALANCE KIT
	SCALE	REV	SHEET

E-194

CONFIGURATION OPTION 3F

GSE DESCRIPTION SHEET

NAME: STAGE WEIGH AND BALANCE KIT EQUIPMENT NO. 173

FUNCTIONAL REQUIREMENT(S):

Determines weight and center of gravity on stage and tilt table.

EQUIPMENT DESCRIPTION:

Similar to DSV-7-321 includes electronics from DSV-4B-345.

10% modification due to changes in center of gravity

COST $ 5,000 (DESIGN AND DEVELOPMENT)

$ 75,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW ____ MODIFIED 10% AS IS ____

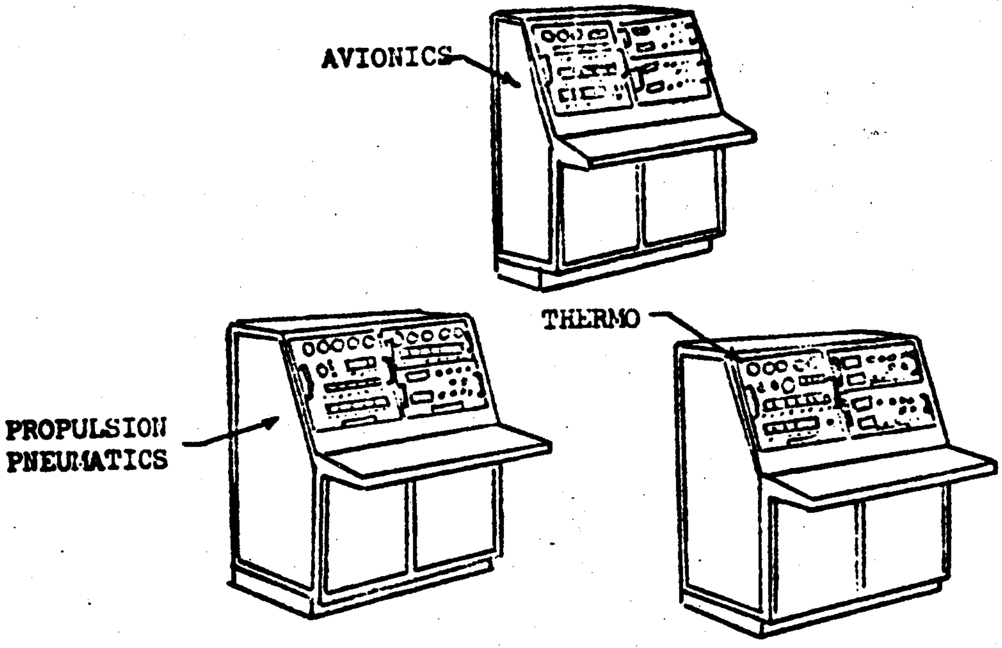
1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.15	TPF/KSC	1 x
	PPF/WTR	1 x

TOTAL REQUIRED 2 TOTAL COST $ 15,000

E-195



SUBSYSTEM MONITORING CONSOLES

GSE DESCRIPTION SHEET

NAME: SUBSYSTEM MONITORING CONSOLES EQUIPMENT NO. 176

FUNCTIONAL REQUIREMENT(S):

Monitors subsystem checkout and count down of avionics subsystems and displays status

EQUIPMENT DESCRIPTION:

Console with intercom, light and indicators, switches, and alpha numerical display (propulsion, avionics, thermo, pneumatics)

COST $ 70,000 (DESIGN AND DEVELOPMENT)

$ 15,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW x WTR MODIFIED ______ AS IS X ETR GFE

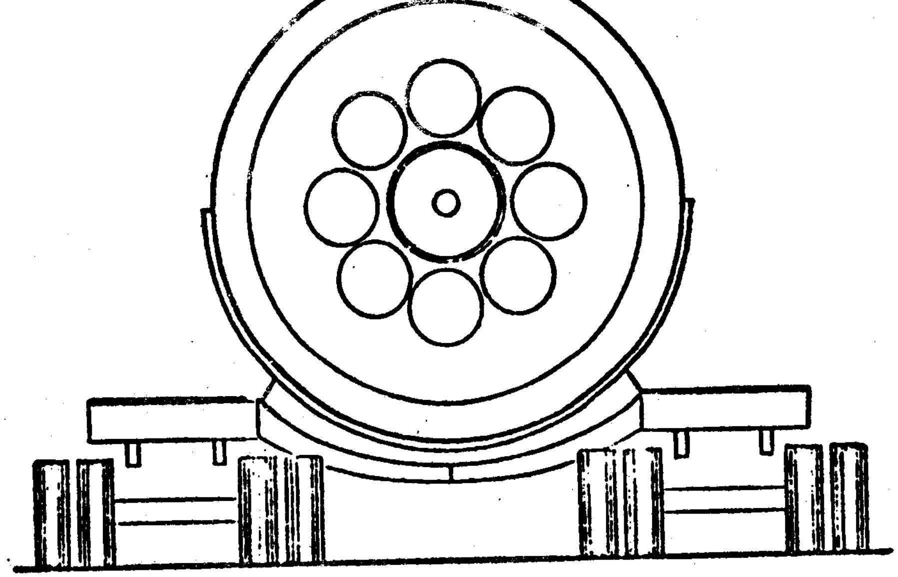
1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

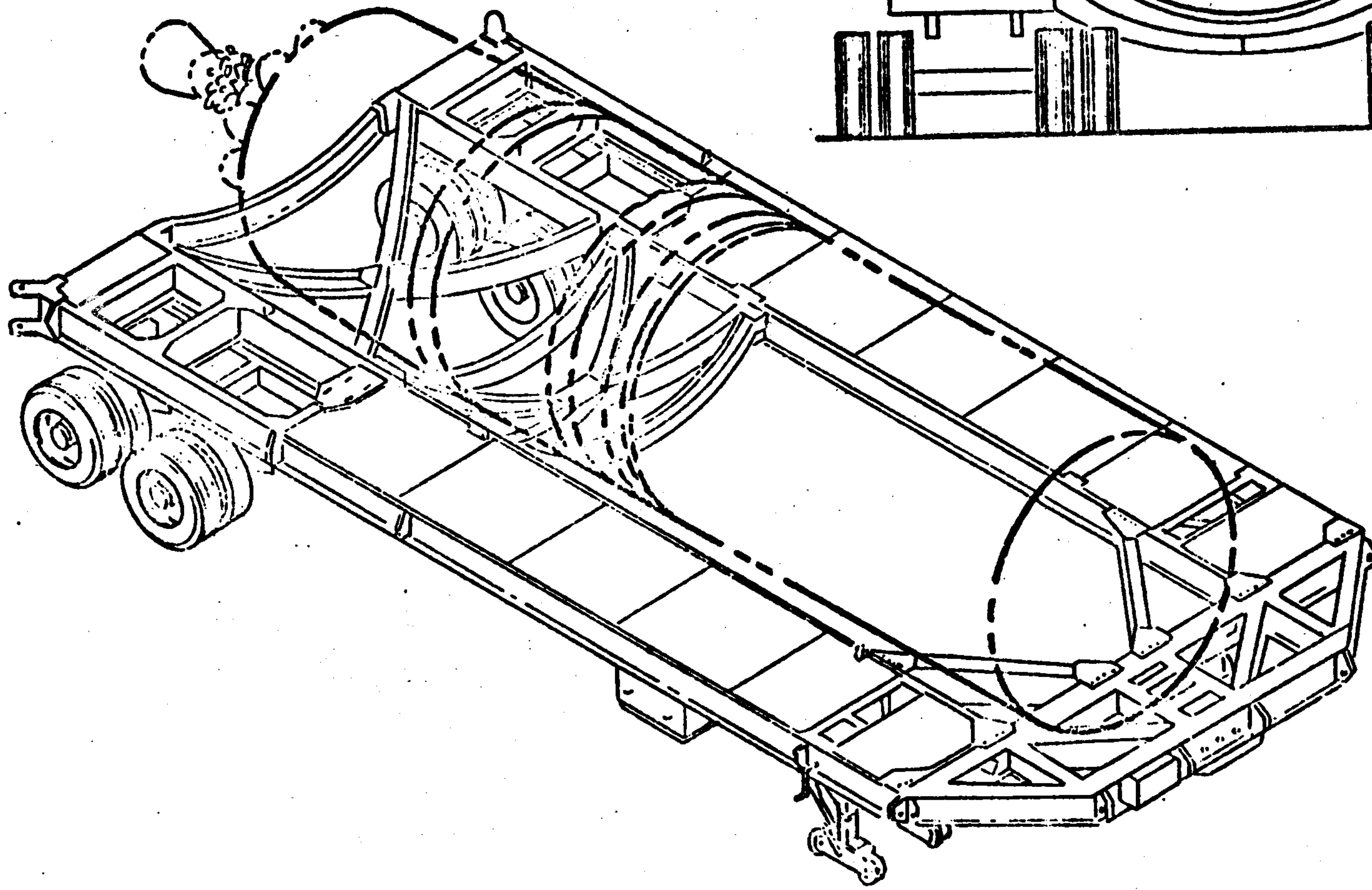
EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.4.3	KSC	
2.4.4	WTR	3

TOTAL REQUIRED 3 TOTAL COST $ 45,000

SPACE TUG - TRANSPORTER
(SIVB MODIFICATION)





GSE DESCRIPTION SHEET

NAME: Transporter EQUIPMENT NO. 183

FUNCTIONAL REQUIREMENT(S):

To give horizontal support and provide mobility to the environmentally protected Tug with a secondary capability for roll and access.

EQUIPMENT DESCRIPTION:

A Saturn SIVB transporter modified to incorporate Saturn Workshop running gear and for provision of Tug compatible cradles.

COST PER UNIT: $ 10,000 (DESIGN AND DEVELOPMENT)

$ 25,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED 20% AS IS 80%

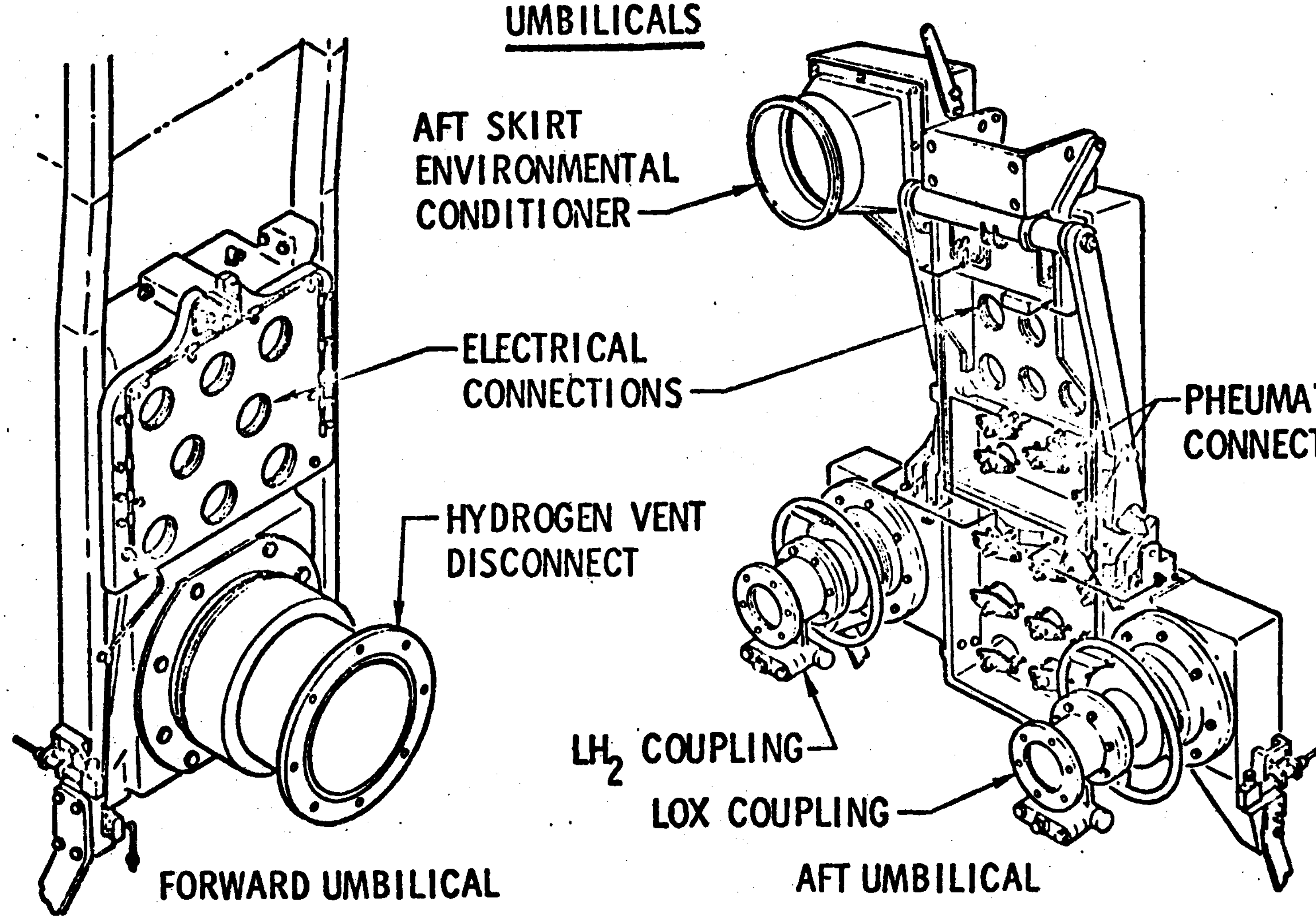
1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.4	KSC	
1.1.2.1	WTR	1
1.1.2.2		
1.1.25		
2.1.4		
2.3.4, 2.4.5		
2.4.8		

TOTAL REQUIRED 1 TOTAL COST $ 25,000

UMBILICALS



UMBILICAL SYSTEM

CONFIGURATION OPTION ________

GSE DESCRIPTION SHEET

NAME: UMBILICAL SYSTEM **EQUIPMENT NO.** 185

FUNCTIONAL REQUIREMENT(S):

Connect test and checkout equipment to vehicle or to orbiter umbilical. Also, used for post flight safing.

EQUIPMENT DESCRIPTION:

Orbiter-half disconnects, ground-half disconnects (if different from orbiter-half), and hoses.

COST $ 400,000 (DESIGN AND DEVELOPMENT)

$ 50,000 (RECURRING/UNIT)

EQUIPMENT CATEGORY:

NEW X MODIFIED ________ AS IS ________

1ST YEAR REQ'D ________ NUMBER AVAILABLE ________

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.5	WTR (Launch pad)	1
2.3.2.2		
2.3.9		
2.4.2		
2.4.5		

TOTAL REQUIRED 1 TOTAL COST $ 50,000

F-201

CONFIGURATION OPTION 3r

GSE DESCRIPTION SHEET

NAME: SIMULATION FLIGHT TEST COMPUTER PROGRAM EQUIPMENT NO. 301

FUNCTIONAL REQUIREMENT(S):

Simulated flight test (integrated system test) verifies Orbiter and Tug operate as a system. Verifies all interfaces in a simulated flight mode approximate 40K.

EQUIPMENT DESCRIPTION:

Magnetic tape or disk, listing and test procedure. Delta cost for development software to final configuration.

COST PER UNIT: $ 89,250 (NON-RECURRING)

$ 30,000 (RECURRING)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED ______ AS IS ______

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
2.3.9	MCF KSC	1
2.4.1	MCF WTR	1
2.4.3	Factory	1

TOTAL REQUIRED 3 TOTAL COST $ 119,250

CONFIGURATION OPTION 3F

GSE DESCRIPTION SHEET

NAME: GROUND CHECKOUT TUG PROCESSING FACILITY COMPUTER PROGRAMS   EQUIPMENT NO. 304

FUNCTIONAL REQUIREMENT(S):

Instrumentation system calibration & test. All system test. Subsystems test (used on long storage Tugs) Programs for ACPS, engine gimballing (sterring), propulsion - pressurization, propellant utilization, engine electronics, and guidance Navigation and control.

EQUIPMENT DESCRIPTION:

Magnetic tape or disk, listing, and test procedure. 181 approximate memory instructions. Propellant utilization 6K, APCS 20K, engine gimballing 20K, propulsion 40K, GN&C 15K, instrumentation system test and control 35K, all system test 45K. Delta cost for software modification to final configuration.

COST PER UNIT: $ 200,000 (NON-RECURRING)

$ 49,800 (RECURRING)

EQUIPMENT CATEGORY:

NEW ____ MODIFIED X AS IS ____

1ST YEAR REQ'D ____ NUMBER AVAILABLE ____

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
1.1.8.9	KSC	1
	WTR	1
	Factory	1

TOTAL REQUIRED 3   TOTAL COST $ 249,800

E-203

CONFIGURATION OPTION 3F

PVT GSE DESCRIPTION SHEET

WBS 32A-07-01

NAME: TEST SOFTWARE COMPUTER PROGRAMS EQUIPMENT NO. 311

FUNCTIONAL REQUIREMENT(S):

Test software to control the propulsion test vehicle testing in J4 test cell at AEDC for static firing.

EQUIPMENT DESCRIPTION:

Magnetic tape or disk, listing, and test procedure. (See attachment)

COST PER UNIT: $ 31,140 (NON-RECURRING)

$ -0- (RECURRING/YEAR)

EQUIPMENT CATEGORY:

NEW ______ MODIFIED X AS IS ______

1ST YEAR REQ'D ______ NUMBER AVAILABLE ______

EQUIPMENT UTILIZATION:

FUNCTIONAL FLOW BLOCK NUMBER	LOCATION REQUIRED	NUMBER REQUIRED
	AEDC J4 Test Cell	1

TOTAL REQUIRED 1 TOTAL COST $ 31,140

11.10 Appendix F Facility Description Sheets

FACILITY DESCRIPTION SHEET

NAME TUG PROCESSING FACILITY LOCATION KSC

FUNCTIONAL PURPOSE:

A central and integrated facility for implementing the required inspection, CO and M&R operations of the Tug and for Tug/SC mating. The facility will provide storage for a maximum of 12 vehicles and work space to permit processing 2 vehicles in parallel. Space will be provided for storage of required spares, for a LOX clean room and for administrative, Q.C., and engineering offices, as required. A class 100K clean environment will be maintained in all but office areas of the building.

FACILITY DESIGN: First floor of KSC-M7-355 shop half O&C Bldg TYPE ________

FLOOR DIMENSIONS ________ FT. X ________ FT. (AREA = 160,000 FT^2)

MAXIMUM CEILING HEIGHT 94 FT.

CLEANLINESS LEVEL REQUIRED 100,000 (Except office areas)

SECURITY REQUIRED X YES ______ NO

FACILITY CATEGORY:

NEW ________ MODIFIED 5% AS IS 95%

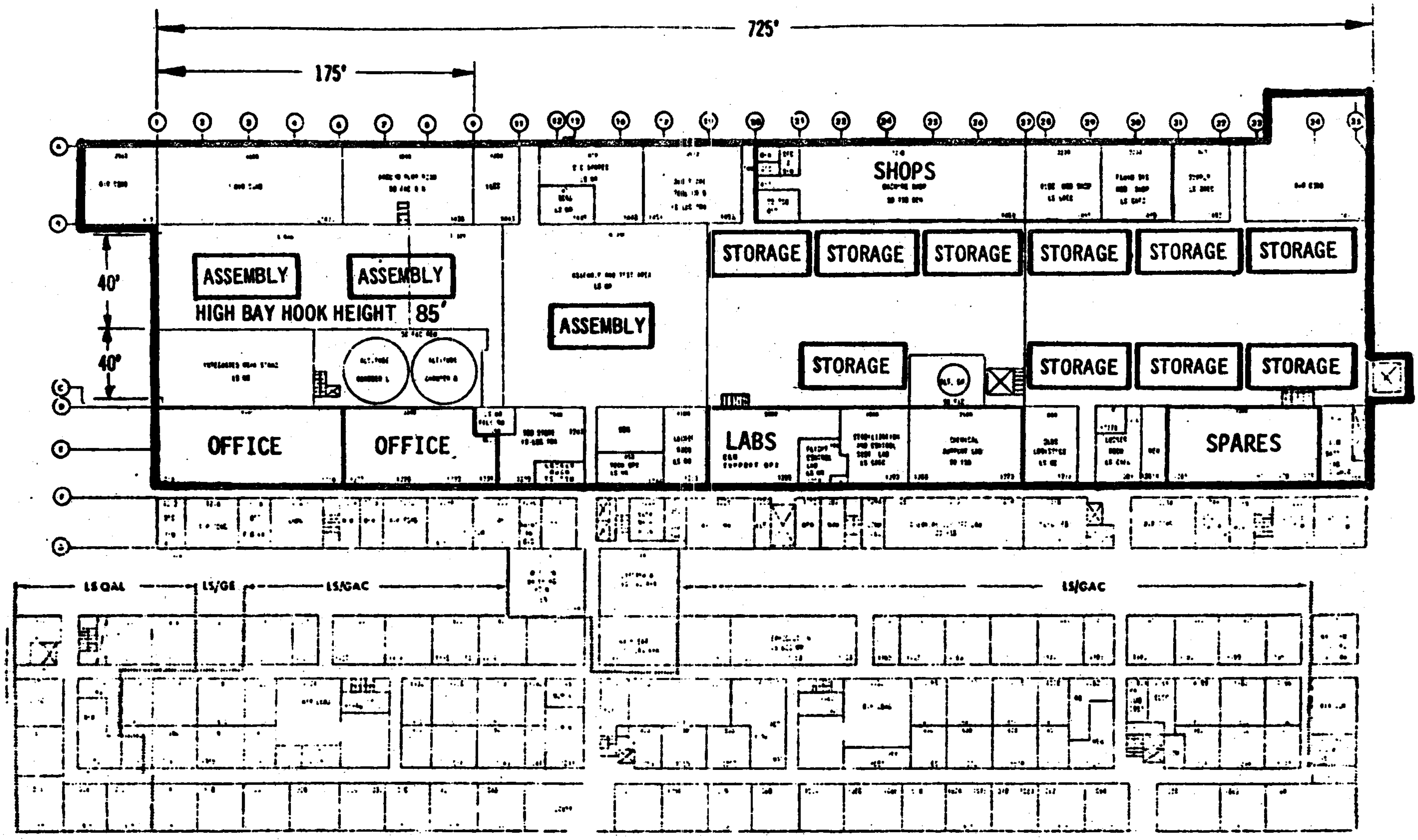
FACILITY COST:

$ 500,000 (NON-RECURRING)

$ ________ (RECURRING/YEAR)

1ST CALENDAR YEAR FACILITY REQUIRED IS ________

TOTAL FACILITY COST IS $ ________



O & C BUILDING FIRST FLOOR, KSC M7-355

SERVICE AREA	24,736 SQ. FT.
AAT AREA	40,730 SQ. FT.
A&E AREA	159,730 SQ. FT.
LSC AREA	123,170 SQ. FT.
TUNNEL AREA	12,020 SQ. FT.
TOTAL	369,312 SQ. FT.

F-3

FACILITY DESCRIPTION SHEET

NAME DOD PAYLOAD PROCESSING FACILITY LOCATION KSC

FUNCTIONAL PURPOSE:

A facility to implement and maintain security for those operations required to prepare DOD Space Craft for mating with Tug. The facility will provide a class 100K clean environment for all areas except that space required for administration, Q.C., and engineering offices.

FACILITY DESIGN: TYPE FAB STEEL

FLOOR DIMENSIONS 100 FT. X 150 FT. (AREA = 15,000 FT^2)

MINIMUM HOOK HEIGHT 65 FT.

CLEANLINESS LEVEL REQUIRED 100,000 CLASS

SECURITY REQUIRED x YES ____ NO

FACILITY CATEGORY:

NEW X MODIFIED ____ AS IS ____

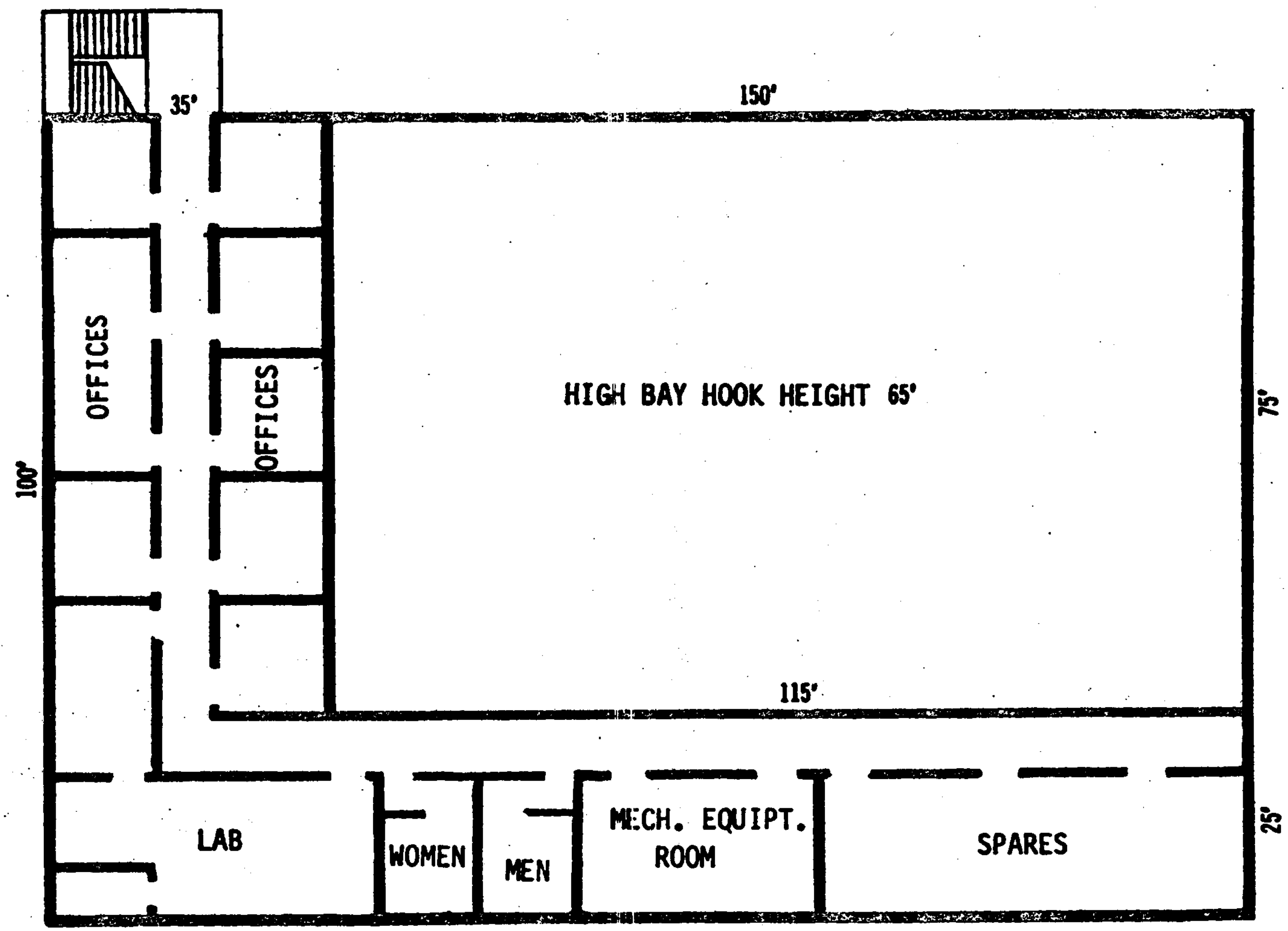
FACILITY COST:

$ 500,000 (NON-RECURRING)

$ ____ (RECURRING/YEAR)

1ST CALENDAR YEAR FACILITY REQUIRED IS ____

TOTAL FACILITY COST IS $ ____



PAYLOAD PROCESSING FACILITY KSC

FACILITY DESCRIPTION SHEET

NAME PAYLOAD PROCESSING FACILITY LOCATION WTR

FUNCTIONAL PURPOSE:

A central and integrated facility for implementing the required inspection, CO and M&R operations of the Tug and for Tug/SC mating. The facility will provide work space to permit processing and/or storage for 2 vehicles. Space will be provided for storage of required spares, for a LOX clean room and for administrative, Q.C., and engineering offices as required. A class 100K clean environment will be maintained in all but office areas of the building.

FACILITY DESIGN: TYPE FAB STEEL

FLOOR DIMENSIONS 150 FT. X 200 FT. (AREA = 30,000 FT^2)

MAXIMUM CEILING HEIGHT 65 FT.

CLEANLINESS LEVEL REQUIRED 100,000 (EXCEPT OFFICE AREAS)

SECURITY REQUIRED X YES ____ NO

FACILITY CATEGORY:

NEW X MODIFIED ____ AS IS ____

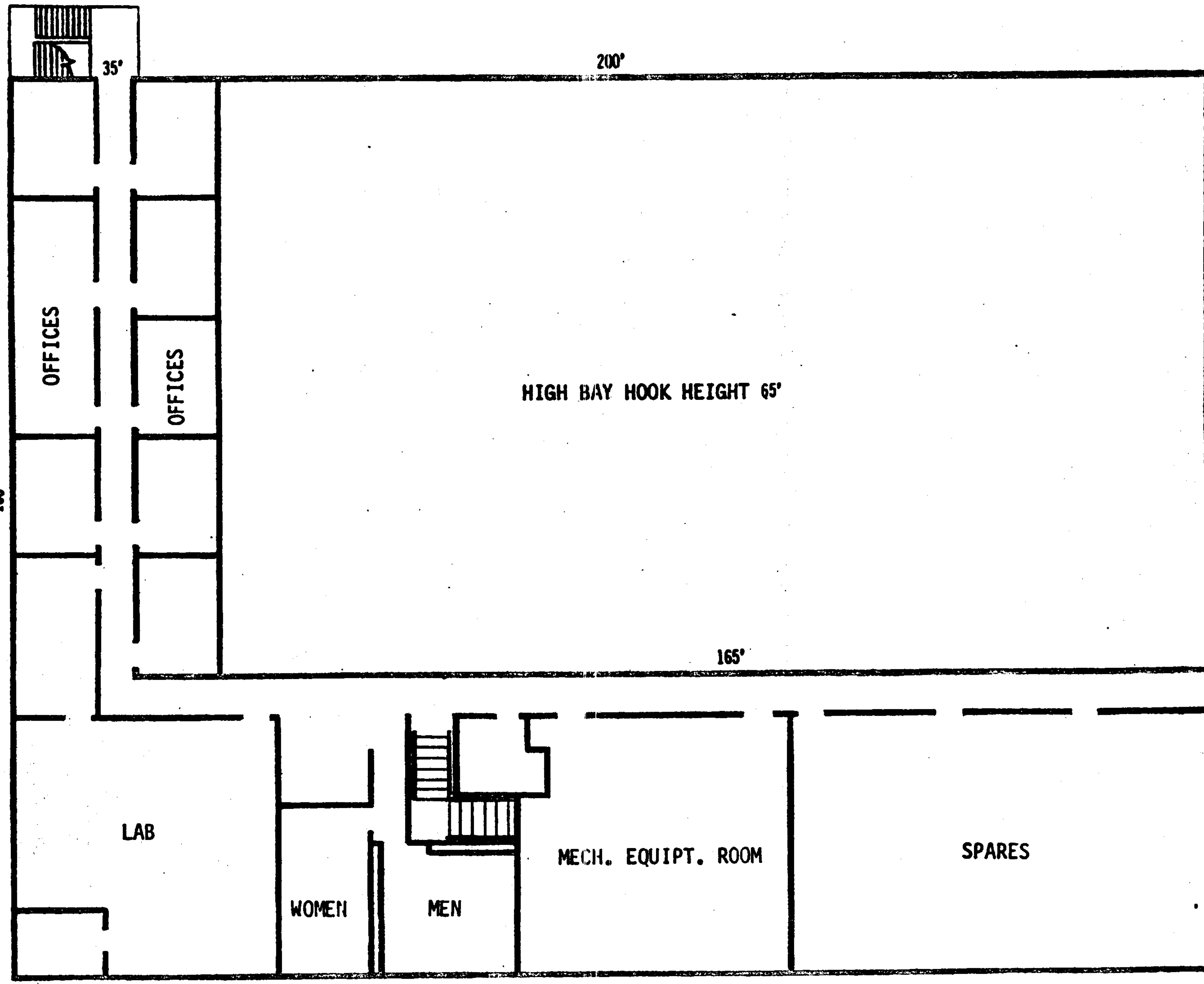
FACILITY COST:

$ 750,000 (NON-RECURRING)

$ ____ (RECURRING/YEAR)

1ST CALENDAR YEAR FACILITY REQUIRED IS ____

TOTAL FACILITY COST IS $ ____



PAYLOAD PROCESSING FACILITY WTR

FACILITY DESCRIPTION SHEET

NAME SHUTTLE MAINTENANCE/CO FACILITY LOCATION KSC

FUNCTIONAL PURPOSE:

The MCF will be modified/designed to provide Tug requirements for floor space to accommodate , I.F. verification and for a Control Center link.

FACILITY DESIGN: TYPE ______

FLOOR DIMENSIONS ______ FT. X ______ FT. (AREA = ______ FT^2)

MAXIMUM CEILING HEIGHT ______ FT.

CLEANLINESS LEVEL REQUIRED ______

SECURITY REQUIRED ______ YES ______ NO

FACILITY CATEGORY:

NEW ______ MODIFIED X AS IS ______

FACILITY COST:

$ 10,000 (NON-RECURRING)

$ ______ (RECURRING/YEAR)

1ST CALENDAR YEAR FACILITY REQUIRED IS ______

TOTAL FACILITY COST IS $ ______

FACILITY DESCRIPTION SHEET

NAME SHUTTLE MAINTENANCE/CO FACILITY LOCATION WTR

FUNCTIONAL PURPOSE:

The MCF will be modified/designed to provide Tug requirements for floor space to accommodate, I.F. verification and for a Control Center link.

FACILITY DESIGN: TYPE ______

FLOOR DIMENSIONS ______ FT. X ______ FT. (AREA = ______ FT^2)

MAXIMUM CEILING HEIGHT ______ FT.

CLEANLINESS LEVEL REQUIRED ______

SECURITY REQUIRED ______ YES ______ NO

FACILITY CATEGORY:

NEW ______ MODIFIED X AS IS ______

FACILITY COST:

$ 10,000 (NON-RECURRING)

$ ______ (RECURRING/YEAR)

1ST CALENDAR YEAR FACILITY REQUIRED IS ______

TOTAL FACILITY COST IS $ ______

FACILITY DESCRIPTION SHEET

NAME LAUNCH SERVICE STRUCTURE (LAUNCH PAD) LOCATION KSC

FUNCTIONAL PURPOSE:

The two Service Towers will be modified/designed to provide access to the Tug in the Shuttle payload bay; Tug propellant load, dump, and vent capability; gas, power, and communication systems and space to store Tug peculiar GSE at point of use.

FACILITY DESIGN: TYPE ________

FLOOR DIMENSIONS ________ FT. X ________ FT. (AREA = ________ FT^2)

MAXIMUM CEILING HEIGHT ________ FT.

CLEANLINESS LEVEL REQUIRED ________

SECURITY REQUIRED ________ YES ________ NO

FACILITY CATEGORY:

NEW ________ MODIFIED X AS IS ________

FACILITY COST:

$ 350,000 (NON-RECURRING)

$ ________ (RECURRING/YEAR)

1ST CALENDAR YEAR FACILITY REQUIRED IS ________

TOTAL FACILITY COST IS $ ________

FACILITY DESCRIPTION SHEET

NAME LAUNCH SERVICE STRUCTURE (LAUNCH PAD) LOCATION WTR

FUNCTIONAL PURPOSE:

The Service Towers will be modified/designed to provide access to the Tug in the Shuttle payload bay; Tug propellant load, dump, and vent capability; gas, power, and communication systems and space to store Tug peculiar GSE at point of use.

FACILITY DESIGN: TYPE ______

FLOOR DIMENSIONS ______ FT. X ______ FT. (AREA = ______ FT^2)

MAXIMUM CEILING HEIGHT ______ FT.

CLEANLINESS LEVEL REQUIRED ______

SECURITY REQUIRED ______ YES ______ NO

FACILITY CATEGORY:

NEW ______ MODIFIED X ______ AS IS ______

FACILITY COST:

$ 350,000 (NON-RECURRING)

$ ______ (RECURRING/YEAR)

1ST CALENDAR YEAR FACILITY REQUIRED IS ______

TOTAL FACILITY COST IS $ ______

FACILITY DESCRIPTION SHEET

NAME LAUNCH CONTROL CENTER LOCATION KSC

FUNCTIONAL PURPOSE:

The Launch Control Center shall be modified to provide a secure room for DOD space craft.

FACILITY DESIGN: TYPE ________

FLOOR DIMENSIONS ______ FT. X ______ FT. (AREA = ______ FT^2)

MAXIMUM CEILING HEIGHT ______ FT.

CLEANLINESS LEVEL REQUIRED ______

SECURITY REQUIRED ______ YES ______ NO

FACILITY CATEGORY:

NEW ______ MODIFIED X AS IS ______

FACILITY COST:

$ 10,000 (NON-RECURRING)

$ ______ (RECURRING/YEAR)

1ST CALENDAR YEAR FACILITY REQUIRED IS ______

TOTAL FACILITY COST IS $ ______

FACILITY DESCRIPTION SHEET

NAME LAUNCH CONTROL CENTER LOCATION WTR

FUNCTIONAL PURPOSE:

The Launch Control Center shall be modified to provide a secure room for DOD space craft.

FACILITY DESIGN: TYPE ________

FLOOR DIMENSIONS ______ FT. X ______ FT. (AREA = ______ FT^2)

MAXIMUM CEILING HEIGHT ______ FT.

CLEANLINESS LEVEL REQUIRED ______

SECURITY REQUIRED ______ YES ______ NO

FACILITY CATEGORY:

NEW ______ MODIFIED X AS IS ______

FACILITY COST:

$ -0- (NON-RECURRING)

$ ______ (RECURRING/YEAR)

1ST CALENDAR YEAR FACILITY REQUIRED IS ______

TOTAL FACILITY COST IS $ ______

FACILITY DESCRIPTION SHEET

NAME SHUTTLE SAFING FACILITY LOCATION KSC

FUNCTIONAL PURPOSE:

The SF will include provisions for Tug propellant storage and transfer and for Tug gas, power, and communication requirements.

FACILITY DESIGN: TYPE ______

FLOOR DIMENSIONS ______ FT. X ______ FT. (AREA = ______ FT^2)

MAXIMUM CEILING HEIGHT ______ FT.

CLEANLINESS LEVEL REQUIRED ______

SECURITY REQUIRED ______ YES ______ NO

FACILITY CATEGORY:

NEW ______ MODIFIED X AS IS ______

FACILITY COST:

$ -0- (NON-RECURRING)

$ ______ (RECURRING/YEAR)

1ST CALENDAR YEAR FACILITY REQUIRED IS ______

TOTAL FACILITY COST IS $ ______

FACILITY DESCRIPTION SHEET

NAME SHUTTLE SAFING FACILITY LOCATION WTR

FUNCTIONAL PURPOSE:

The SF will include provisions for Tug propellant storage and transfer and for Tug gas, power, and communication requirements.

FACILITY DESIGN: TYPE ____________

FLOOR DIMENSIONS ________ FT. X ________ FT. (AREA = ________ FT^2)

MAXIMUM CEILING HEIGHT ________ FT.

CLEANLINESS LEVEL REQUIRED ____________

SECURITY REQUIRED ________ YES ________ NO

FACILITY CATEGORY:

NEW ________ MODIFIED X AS IS ________

FACILITY COST:

$ -0- (NON-RECURRING)

$ ____________ (RECURRING/YEAR)

1ST CALENDAR YEAR FACILITY REQUIRED IS ____________

TOTAL FACILITY COST IS $ ____________

FACILITY DESCRIPTION SHEET

NAME STORABLE PROPELLANT FACILITY LOCATION KSC

FUNCTIONAL PURPOSE:

The SPS will provide space for mobile GSE used in propellant storage and transfer operations for Tug pod, separate tank or integral APS systems.

FACILITY DESIGN: TYPE ______

FLOOR DIMENSIONS 50 FT. X 100 FT. (AREA =5000 FT^2)

MAXIMUM CEILING HEIGHT 30 FT.

CLEANLINESS LEVEL REQUIRED ______

SECURITY REQUIRED ______ YES ______ NO

FACILITY CATEGORY:

NEW ______ MODIFIED x AS IS ______

FACILITY COST:

$ -0- (NON-RECURRING)

$ ______ (RECURRING/YEAR)

1ST CALENDAR YEAR FACILITY REQUIRED IS ______

TOTAL FACILITY COST IS $ ______

FACILITY DESCRIPTION SHEET

NAME STORABLE PROPELLANT FACILITY LOCATION WTR

FUNCTIONAL PURPOSE:

The SPF will provide space for mobile GSE used in propellant storage and transfer operations for Tug pod, separate tank or integral APS systems.

FACILITY DESIGN: TYPE ______

FLOOR DIMENSIONS 50 FT. X 100 FT. (AREA = ______ FT^2)

MAXIMUM CEILING HEIGHT 30 FT.

CLEANLINESS LEVEL REQUIRED ______

SECURITY REQUIRED ______ YES ______ NO

FACILITY CATEGORY:

NEW ______ MODIFIED x AS IS ______

FACILITY COST:

$ -0- (NON-RECURRING)

$ ______ (RECURRING/YEAR)

1ST CALENDAR YEAR FACILITY REQUIRED IS ______

TOTAL FACILITY COST IS $ ______

FACILITY DESCRIPTION SHEET

NAME VERTICAL ASSEMBLY BUILDING LOCATION ETR

FUNCTIONAL PURPOSE:

The VAB will be modified as required to integrate and install GSE peculiar to Tug requirements for monitoring storable propellants.

FACILITY DESIGN: TYPE ____________

FLOOR DIMENSIONS ________ FT. X ________ FT. (AREA = ________ FT^2)

MAXIMUM CEILING HEIGHT ________ FT.

CLEANLINESS LEVEL REQUIRED ____________

SECURITY REQUIRED ________ YES ________ NO

FACILITY CATEGORY:

NEW ________ MODIFIED X ________ AS IS ________

FACILITY COST:

$ 10,000 (NON-RECURRING)

$ ____________ (RECURRING/YEAR)

1ST CALENDAR YEAR FACILITY REQUIRED IS ____________

TOTAL FACILITY COST IS $ ____________

FACILITY DESCRIPTION SHEET

NAME VERTICAL ASSEMBLY BUILDING LOCATION WTR

FUNCTIONAL PURPOSE:

The VAB will be designed as required to integrate and install GSE peculiar to Tug requirements for monitoring storable propellants.

FACILITY DESIGN: TYPE ______

FLOOR DIMENSIONS ______ FT. X ______ FT. (AREA = ______ FT^2)

MAXIMUM CEILING HEIGHT ______ FT.

CLEANLINESS LEVEL REQUIRED ______

SECURITY REQUIRED ______ YES ______ NO

FACILITY CATEGORY:

NEW ______ MODIFIED X ______ AS IS ______

FACILITY COST:

$ 10,000 (NON-RECURRING)

$ ______ (RECURRING/YEAR)

1ST CALENDAR YEAR FACILITY REQUIRED IS ______

TOTAL FACILITY COST IS $ ______

FACILITY DESCRIPTION SHEET

NAME HIGH VACUUM TEST FACILITY (4557) LOCATION Huntsville, Ala

FUNCTIONAL PURPOSE:

Conduct thermal testing.

FACILITY DESIGN: TYPE ________

FLOOR DIMENSIONS ________ FT. X ________ FT. (AREA = ________ FT^2)

MAXIMUM CEILING HEIGHT ________ FT.

CLEANLINESS LEVEL REQUIRED ________

SECURITY REQUIRED ________ YES ________ NO

FACILITY CATEGORY:

NEW ________ MODIFIED ________ AS IS ________

FACILITY COST:

NASA -0-
DOD $ 250,000 (NON-RECURRING)

$ ________ (RECURRING/YEAR)

1ST CALENDAR YEAR FACILITY REQUIRED IS ________

TOTAL FACILITY COST IS $ ________

FACILITY DESCRIPTION SHEET

NAME AEROSPACE ENVIRONMENTAL CHAMBER (MARK I) LOCATION AEDC, TULLAHOMA, TENN.

FUNCTIONAL PURPOSE:

Conduct PTV tests.

FACILITY DESIGN: TYPE ____________

FLOOR DIMENSIONS ________ FT. X ________ FT. (AREA = ________ FT^2)

MAXIMUM CEILING HEIGHT ________ FT.

CLEANLINESS LEVEL REQUIRED ____________

SECURITY REQUIRED ________ YES ________ NO

FACILITY CATEGORY:

NEW ________ MODIFIED ________ AS IS ________

FACILITY COST:

NASA $1,250,000
DOD $ -0- (NON-RECURRING)

$ ____________ (RECURRING/YEAR)

1ST CALENDAR YEAR FACILITY REQUIRED IS ____________

TOTAL FACILITY COST IS $____________

12.0 Tradeoffs and Sensitivities

This section contains specific tradeoffs and sensitivities as specified in the Data Dump Outline. Also included are additional data in section 12.7, "Other Sensitivities" which provide further information in selected trade studies.

12.1 Velocity Package Sizing

Because of their high energy requirements, only the planetary missions are candidates for using a large kick stage. The requirements for these missions are shown in Table 12.1-1. Only misstions 17 and 18 can be flown in a fully reusable mode. The other missions, 19 through 24, would require either flying the Tug in an expendable mode or, if possible, flying the Tug reusable with an expendable kick stage.

A schematic mission profile using a kick stage is shown in Figure 12.1-1. The Tug burns into an initial phasing orbit, 1 and then slightly before perigee does a second burn into an intermediate orbit, 2 The use of a phasing orbit is two-fold. It not only allows for minor timing adjustments, it affects a two burn departure which significantly reduces gravitational losses. Shortly after this burn the Tug separates from the kick stage-payload, 3. The Tug then retros into a return orbit with a perigee near Shuttle rendezvous altitude, 4. This is necessary on all missions, even though in some cases the Tug has not reached escape velocity, because the period of the orbit without retro exceeds Tug mission duration capability. After deployment from the Tug, once sufficient separation has been achieved the kick stage is fired, 5 sending the payload into an interplanetary solar orbit.

Using this mission profile the performance of the Tug/kick stage combination, over a range of kick stage sizes was determined. The Tug was flown off loaded, such that the combined weight of the Tug-kick stage-payload did not exceed the Shuttle deployment capability (including ancillary Tug equipment left in the Shuttle). The kick stage performance was based on Isp and λ'valves consistent with current state of the art solid rocket motor stages. This performance is shown on Figure 12.1-2 for the missions of interest. By comparing the performance with the current design payload weights shown in the previous table, it can be seen that missions 22 and 24 are unobtainable over the entire range of kick stage weights. The other missions are achievable over the range of sizes, except for a small portion of mission 23.

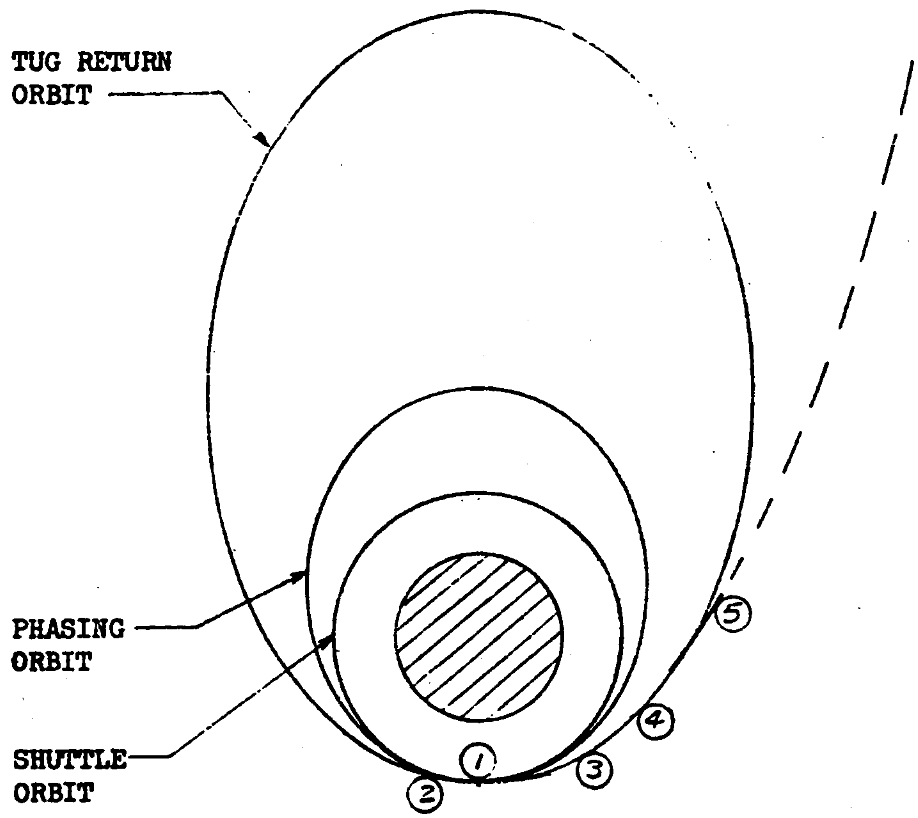
Table 12.1-1

TYPICAL MISSION MODEL
FOR
SPACE TUG SYSTEMS STUDY
(DESCRIPTIVE DATA)

	PAYLOAD NUMBER	INCL. i°	$H_a \times H_p$ (n.m.)	V(fps) (160 n.m.)	CURRENT DESIGN			LOW COST DESIGN		
					DIAMETER (ft)	LENGTH (ft)	WEIGHT (lbs.)	DIAMETER (ft)	LENGTH (ft)	WEIGHT (lbs.)
PLANETARY	17			13000	10	12	1000	14	12	2000
	18			13000	10	12	2000	14	10	3300
	19			16500	12	20	5500	14	20	7900
	20			23000	10	17	900	14	14	1500
	21			24000	10	15	1600	14	15	2500
	22			24000	12	16	2500	14	18	4000
	23			18400	12	17	5000	14	16	6600
	24			22000	12	17	3300	14	15	4400

KICK STAGE

INTERPLANETARY INJECTION MISSION



1. BURN INTO PHASING ORBIT
2. BURN INTO INTERMEDIATE ORBIT
3. KICK STAGE/PAYLOAD SEPARATION
4. RETRO BURN INTO RETURN ORBIT
5. KICK STAGE BURN INTO INTERPLANETARY SOLAR ORBIT

Figure 12.1-1

THE EFFECT OF KICK STAGE PROPELLANT WEIGHT ON
MISSION PAYLOAD
OPTION 3I & 3F

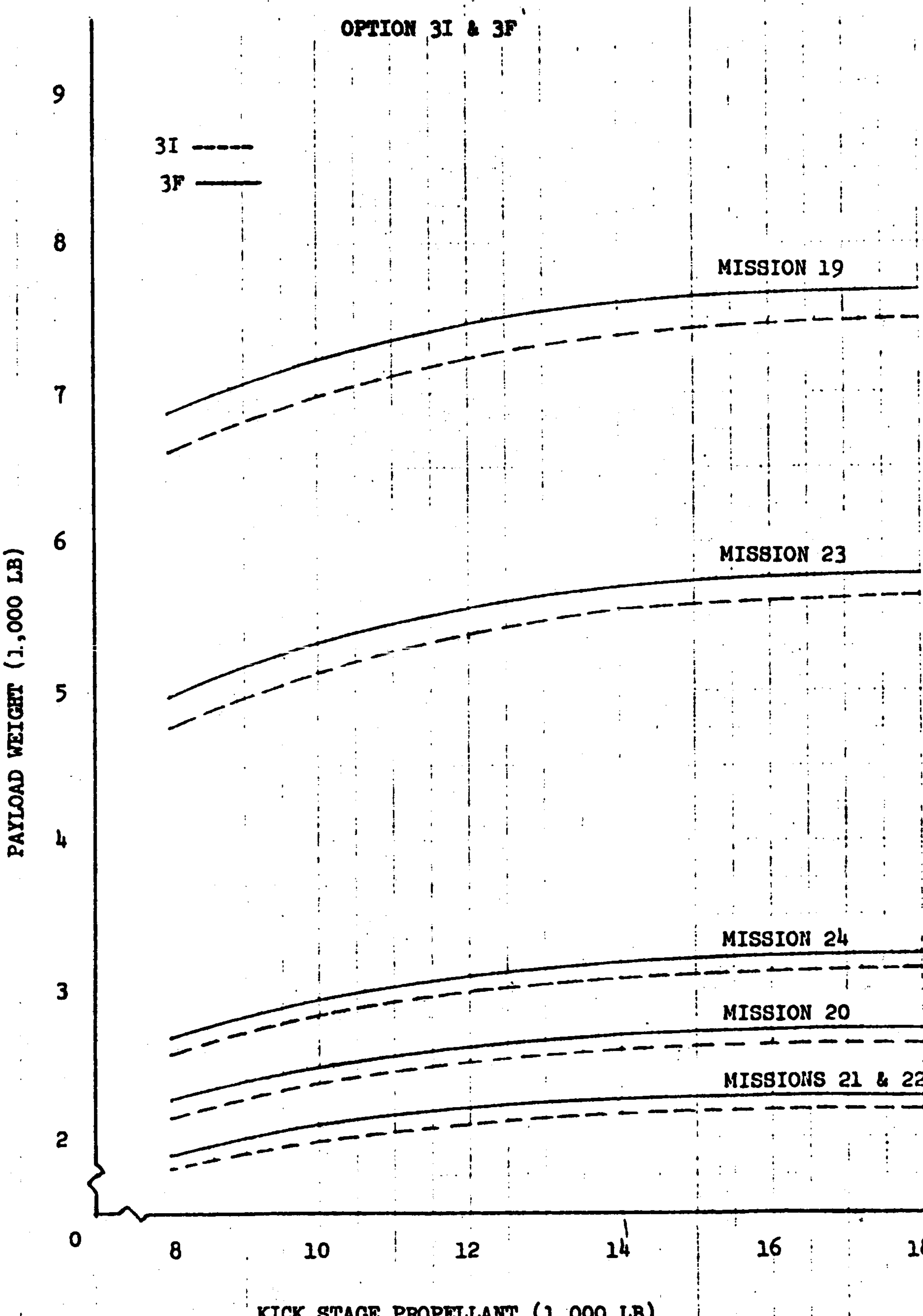


Figure 12.1-2

Because of the strong emphasis on low costs, especially DDT&E, there was high motivation to find an existing stage within this size class. Performance alone was not the criteria for selection and other constraints had to be applied. These were stage length and thrust/time characteristics of the motor. The combined length of the Tug-kick stage-payload could not exceed 60 feet and peak longitudinal accelerations could not exceed 3.5 g's.

The only existing stage that came close to satisfying all the requirements was the Polaris A3 second stage. Its performance was adequate, it satisfied the length constraints and required only minor modifications to meet the thrust limitations.

Option 3I requires the use of a kick stage on one flight of DOD mission 11a. The Polaris is well above optimum size for this mission, but can be flown in a non-optimum trajectory to satisfy the mission. This mode was chosen rather than procuring an additional smaller kick stage because it would be cheaper to buy one more Polaris than to integrate a different additional kick stage into the program.

12.2 Expendable Tug vs. Tug On-Orbit Assembly

The basic Option 3 program involves expending 8 Tugs (4 of Initial and 4 of Final Configuration) in the performance of 8 interplanetary missions (NASA 22 and 24). Consideration of using two Tugs to provide sufficient energy to perform the missions was made. With the Option 3 Initial Configuration significant modifications to the vehicle are required since it is limited in duration, has no docking capability and has no inter-stage structure. In the Final Configuration only the inter-stage structure needs to be added. Table 12.2-1 shows the comparison of the cost impact of adding these capabilities and the impact on the total program costs. The DDT&E costs associated with rendezvous and docking and extending duration already are necessary in the Final Configuration so the only impact in DDT&E would be the cost of the inter-stage and the moving of about $20 millions from the final configuration to the initial configuration DDT&E.

From the data presented in the Table it was concluded that the expendable mode was more cost effective.

COST COMPARISON

EXPENDABLE TUG VS ON-ORBIT ASSEMBLY

OPTION 1

CATEGORY	EXPENDABLE TUG (MILLIONS)	ON-ORBIT ASSEMBLY (MILLIONS)
TUG FLEET	5 I Tugs = 98.6	5 I Tugs = 98.6
	11 F Tugs = 176.8	6 F Tugs = 103.0
OPERATIONS INCREASES		
8 ADDITIONAL SHUTTLE FLIGHTS	-	84.00
FLIGHT OPERATIONS	-	
DDT&E	-	2.20
OPS		0.32
INTERSTAGE SYSTEM	-	
DDT&E		0.58
PRODUCTION		0.24
RELIABILITY IMPACT	-	18.32
TOTAL	275.4	307.24

TABLE 12.2-1

12.3 Multiple Deployment Analysis

12.3.1 Mission Accomplishment Impact

A major advantage of the STS over current expendable systems is the capability of deploying several payloads in different orbital positions. In the basic option 3 program multi-deployments were used with both the initial and final configurations. If the configurations were allowed to deploy only one payload per mission, the number of flights would increase by 56 over the 11 year program (assuming that retrieval was allowed in conjunction with a deployment). The 56 flights would increase the program cost by about $645 millions in operations and production by about $16 millions.

12.3.2 Multiple Payload Delivery Options

Figure 12.3.2-1 summarizes several multipayload support concepts. This comparison was done at the conceptual level only as the definition of payload support was not included in the Space Tug Systems Study.

The minimum adaptor structure was defined for the Tandem stack concept. This arrangement has the greatest impact on payload structure because the lower payloads must support the cantilevered loads of the forward payloads.

The second option, parallel payloads, minimizes the payload structural impacts but severely constrains the payload diameters.

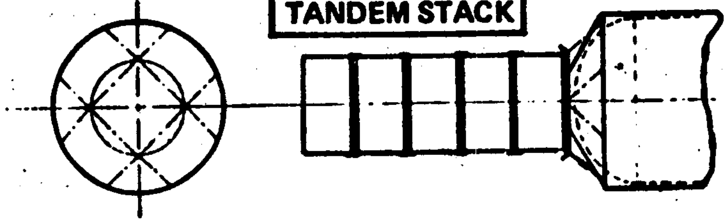
The third option grossly complicates the Tug/Shuttle interface by creating a Shuttle/payload interface.

The final option, which is the preferred option, utilizes a retractable (collapsible) support truss. After the forward payload is deployed, the square frame portion of the support truss is expanded (enlarged) and the frame is folded back against the succeeding frame, exposing the next payload for deployment. This is repeated after each deployment. A detailed description of a similar mechanism used to enlarge the square frame is given in Volume V Section 4.3 in a discussion of an automatic variable diameter docking system.

The DDT&E for this system is estimated to be at least equal to that of the Tug docking system or approximately $4 million.

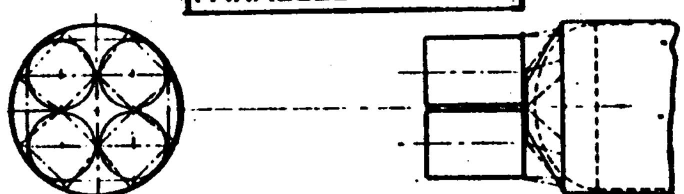
MUTLTIPLE PAYLOAD DELIVERY OPTIONS

TANDEM STACK



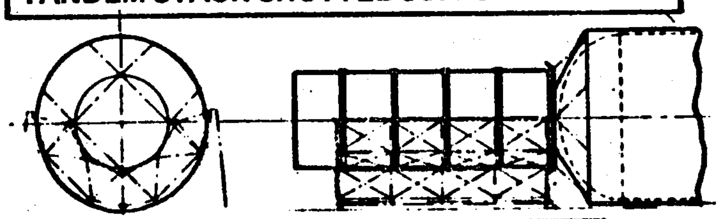
- EXTREME IMPACT ON PAYLOAD STRUCTURE
- SEPARATION ORDNANCE REQD ON FWD PAYLOADS
- COMPATIBLE WITH SINGLE PAYLOAD RETRIEVAL
- MINIMUM ADAPTOR STRUCTURE

PARALLEL PAYLOADS



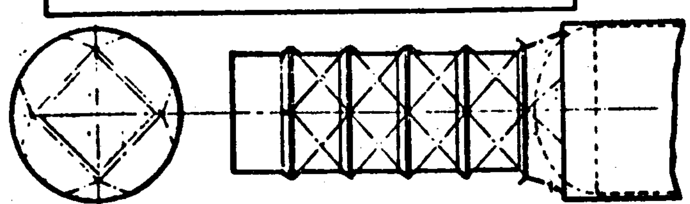
- POOR PAYLOAD CLEARANCE AT SEPARATION
- MINIMUM PAYLOAD IMPACT, SMALL ADAPTOR STRUCTURE
- MAY BE COMPATIBLE WITH SINGLE RETRIEVAL
- PAYLOAD DIAM CONSTRAINED
  2 PAYLOADS/87 IN. – 3 PAYLOADS/80 IN.
  4 PAYLOADS/72 IN.
- LATERAL C.G. EXCURSION DURING FLIGHT

TANDEM STACK SHUTTLE SUPPORT CRADLE



- COMPATIBLE WITH RETRIEVAL
- DECOUPLED FROM TUG THROUGH ASCENT
- PAYLOAD/PAYLOAD INTERFACE IMPACT
- PAYLOAD SEPARATION ORDNANCE REQUIRED
- LARGE CRADLE STRUCTURE; REMAINS IN BAY

RETRACTABLE SUPPORT TRUSS



- LEAST PAYLOAD IMPACT
- COMPATIBLE WITH SINGLE RETRIEVAL
- NO SEPARATION PROBLEM
- FOLDING SUPPORT FLIES WITH TUG
- VARIABLE P/L DIAMETER ACCOMMODATION

RECOMMEND RETRACTABLE SUPPORT TRUSS CONCEPT

12.4 Autonomy Sensitivities

12.4.1 Program Variation Identification and Sensitivity Summary

The Tug defined for Option 3F provides the capabilities associated with autonomy level III. This analysis addresses the sensitivity to other autonomy levels. The various autonomy levels are defined as follows:

AUTONOMY LEVEL IV

- All phases are controlled from the ground.

  A portion of the mission control/sequencing is under ground control. Powered flight, contingencies and non-ground coverage control/sequencing will still be implemented on board. The ground basically has extensive on board program load/updating capability.

- Calculations are performed primarily on the ground (such as main burn and midcourse - duration and direction).

  All calculations that can feasibly be performed on the ground have been removed from the on board software. The ground is responsible for vehicle attitude update (utilizing on board star tracker measurements), targeting to determine ΔV required/burn time, tug position/velocity update during coast and possibly some redundancy management during coast.

- Ground will control final rendezvous and docking.

  The acquisition guidance, closure guidance, and docking guidance will be performed under ground control. Laser radar data (if applicable) will be filtered on board.

  NOTE: There is a potential problem transmitting TV data on DOD missions due to the security requirement.

- Command and Telemetry Capability

  The ground (or Orbiter) will have the capability of transmitting real time hardwire uplink commands. This capability will be relatively constant for all autonomy levels since it is almost independent of flight software. All vehicles will transmit TM data.

  In addition the capability for ground update of on board application programs will also not be a function of autonomy level, but the need (or requirement) for such an update will be a function of autonomy level.

AUTONOMY LEVEL III

- Ground stations provide state update during entire mission.

  The ground stations will determine vehicle position/velocity and update the flight software. The vehicle attitude update is handled on board.

- Onboard calculations are performed for mission completion.

  All mission control/sequencing required to complete the nominal mission is resident in the on board software. The ground will have override capability via the uplink. In addition, the targeting function is carried on board. Targeting is the capability of updating the ΔV/burn time based on a predetermined mission.

- Final rendezvous is made by on board capability.

  The target acquisition and closure guidance are performed on board. Radar data processing is performed on board.

- Final docking with ground support.

  The docking guidance is provided by the ground.

- Command and telemetry capability.

  Same as autonomy Level IV.

AUTONOMY LEVEL II

- Ground or navigation satellite beacons (either must serve multiple users) are acceptable.

- Level I autonomy will be required for those orbits where ground or satellite beacons do not provide satisfactory state determination.

- Final on board rendezvous and docking capability.

  Same as Level I

- Command uplink override capability including payload status, redirection and retargeting of mission with telemetry down link.

  Mission planning capability is added to the on board software. The mission planning software will accept new target ephemerous/mission definition and determine a mission plan (i.e., number of burns, ΔV's, time, location, etc.).

AUTONOMY LEVEL I

- o Completely independent of any man made inputs after separation.
  All nominal mission control/sequencing is performed on board. The vehicle is capable of sutonomous state (Pos/Vel/Att) update independent of any ground navigation aids. All capabilities in Level III are also included in Level I.
- o On board measurements and calculations enable missions to be completed in its entirety including all Tug and payload operations.
  Payload checkout/commanding is accomplished with vehicle software independent of required ground control although ground override capability can be provided. This requirement adds payload uplink/downlink TM equipment to the Tug.
- o Final onboard rendezvous and docking capability
  All phases of rendezvous guidance are controlled via the on board software. All sensor data is processed on board.
- o Command uplink override capability and telemetry down link.
  Same as other levels.

The sensitivities to the various autonomy levels are shown in Table 12.4-1. Autonomy Level IV results in a $7.61 million reduction in program cost with no impact on vehicle performance. Other autonomy levels result in increased cost and decreased performance. A cost breakdown is summarized in Table 12.4-2. The savings in program cost for Level IV autonomy results from the decrease in DDT&E and operations cost. This result is significantly different from the direct developed tugs in which autonomy level IV was the lowest total cost. This difference results in a phased program because DDT&E cost for both level III and IV is incurred in a phased program whereas either level III or IV DDT&E cost is incurred in a direct developed program.

TABLE 12.4-1

AUTONOMY SENTIVITIES

	AUTONOMY LEVELS		
	~~III~~ IV	II	I
TOTAL PROJECT COST* ($M)	-7.61	26.19	20.96
PAYLOAD DEPLOYED (LBS)	-5.4	-549	-549
VEHICLE WEIGHT (LBS)	2	204	204
ELECTRICAL POWER (WATTS)	0	248	248

* Does not include unscheduled maintenance and refurbishment

TABLE 12.4-2

Autonomy Cost Sensitivities

(1973 Dollars in Millions)

WBS NO.	WBS IDENTIFICATION	AUTONOMY LEVELS IV	II	I
DDT&E				
320-03-03	Avionics	-2.18	12.71	11.47
320-07	GSE	-0.71	1.63	0.79
320-11/12	Flight Operations-NASA/DOD	-6.87	4.54	2.32
320	Total Project-DDT&E	-9.76	18.88	14.58
PRODUCTION				
320-03-03	Avionics	-0.02	6.30	6.30
320	Total Project - Production	-0.02	6.30	6.30
OPERATIONS*				
320-03-03	Avionics (Software update)	-1.23	2.01	1.18
320-07	GSE (Software update)	-0.08	0.16	0.06
320-11/12	Flight Operations-NASA/DOD	3.48	-1.16	-1.16
320	Total Program - Operations	2.17	1.01	0.08
320	TOTAL PROJECT COST	-7.61	26.19	20.96

* Does not include unscheduled maintenance

Assumptions/Ground Rules

As a minimum all autonomy levels require onboard redundancy management during powered flight. Since the reaction time required to switch redundant units during coast periods is less critical, redundancy management function peculiar to this phase could possibly be ground controlled.

For the higher autonomy levels (II & I), automatic payload checkout capability is added to the Tug Data Management subsystem since the vehicle may be out of contact with the ground during payload deployment.

The command override via the uplink will be implemented by one of the following methods; real time hardwire commands, real time software commands, program update, and new program load. The real time hardwire commands bypass the onboard computer and control the component directly. These commands are safety in nature and can be transmitted from the ground or Orbiter. The sender must account for the action of the onboard software during these situations. The real time software commands are executed via the onboard software. The capability of transmitting these commands has therefore been pre-planned during the writing of the onboard software. Commands that update the onboard software are similar to real time hardwire commands since they require pre-planned logic, but they affect subsequent program logic. These commands could load data required by the program, update existing data, control program mode, set flags, store program commands, etc. The requirement for providing the capability of an orbit program modification is questionable along with the implementation, so it will not be elaborated on here. The capability of loading a new program could possibly be restricted to checkout programs limited to a portion of the memory or to a complete onboard software load as the ultimate.

The real time hardwire command override capability as defined herein is not considered to be a function of autonomy level since its function is safing and reinitialization of the tug and this function is independent of autonomy level.

The requirement for real time software commands is analogous to the hardwire commands and are also not a function of autonomy level.

The requirements for program update data is a function of autonomy level although the capability of providing it is not. The requirement for ground update are reflected as changes in the application program estimates.

Program modification/load commands are not considered a function of autonomy even though they infer a level of ground support.

During powered flight the guidance (steering), flight control, state (attitude/position/velocity) determination, and subsystem control/redundancy management will be performed onboard. It is not considered feasible to perform these functions on the ground.

12.4.2 Configuration Variations

- o Structures - no impact
- o Propulsion - no impact
- o Avionics

Data Management Subsystem

Table 12.4-3 summarizes the software requirements for the various autonomy levels. The baseline system uses a two 16 bit control computer with 24000 words of storage. Decreasing the autonomy to level IV results in a reduction of 6125 words of storage. Because of the margin, a reduction of an 8K module from the baseline computer is possible.

In addition to the software changes shown in Table 12.4-3, 3000 words of storage are required for payload checkout in autonomy levels I and II.

For autonomy levels II and I two additional 16 bit-24K computers and Data Interface units (DIU) are required to handle the increased computations and maintain the same redundancy level. The resultant sensitivities are summarized below.

	Autonomy Level		
	IV	II	I
DDT&E ($\overline{M}$$)	-2.18	3.36	2.12
Weight (Lb)	-2.0	40	20
Power (Watts)	Neg	156	156

TABLE 12.4-3

	IV MEM	IV EXEC TIME (ms) 16	IV EXEC TIME (ms) 24	IV EXEC TIME (ms) 32	III MEM	III EXEC TIME (ms) 16	III EXEC TIME (ms) 24	III EXEC TIME (ms) 32	II MEM	II EXEC TIME (ms) 16	II EXEC TIME (ms) 24	II EXEC TIME (ms) 32	I MEM	I EXEC TIME (ms) 16	I EXEC TIME (ms) 24
DATA MANAGEMENT															
EXECUTIVE	1670	42	0	0	1670	42	0	0	1670	42	0	0	1670	42	0
MISSION CONTROL	300	0	0	1	500	1	0	0	500	0	0	1	500	0	0
MATH SUBROUTINES	335	-	-	-	800	-	-	-	800	-	-	-	800	-	-
UPLINK PROC	200	0	0	1	200	0	0	1	200	0	0	1	200	0	0
NAVIGATION															
GROUND ALIGNMENT	300	0	0	0	300	0	0	0	300	0	0	0	300	0	0
SUBROUTINES	40	0	0	0	460	0	0	0	610	0	0	0	610	0	0
ATTITUDE UPDATE (IMU)Δ	1365	40	225	1	1365	40	225	1	1365	40	225	1	1365	40	225
ATTITUDE UPDATE (S.T)	150	0	0	0	2300	0	0	0	2300	0	0	0	2300	0	0
POS/VEL DET - IMUΔ	1290	40	167	2	1290	40	167	2	1290	40	167	2	1290	40	167
POS/VEL DET - ORB INT	250	0	0	0	250	0	0	0	1800	0	0	0	1800	0	0
POS/VEL UPDATE - HS	100	0	0	0	0	0	0	0	1080	0	0	0	1080	0	0
GUIDANCE															
MISSION PLANNING	0	0	0	0	0	0	0	0	4500	0	0	0	0	0	0
TARGETING	0	0	0	0	2000	0	0	0	2000	0	0	0	2000	0	0
PWR FLT GUID	950	42	0	0	950	42	0	0	2100	42	70	0	2100	42	70
COAST ATT PROFILE	335	0	0	0	335	0	0	0	335	0	0	0	335	0	0
FLIGHT CONTROL	1660	71	110	0	1660	71	110	0	1660	71	110	0	1660	71	110
SUBSYSTEM CONT/MONT															
PRE-DEPLOY C/O	500	-	-	-	500	-	-	-	500	-	-	-	500	-	-
IN FLT CONT/MONT	1000	2	0	0	2000	4	0	0	2000	4	0	0	2000	4	0
ON BOARD C/O	2000	0	0	0	2000	0	0	0	2000	0	0	0	2000	0	0
TOTAL V. SOFTWARE	12445	237	502	5	16570	240	502	4	27010	239	572	5	22510	239	572
TOTAL EXEC TIME*				744				746				816			
-RDP REQ'MTS	2655	80	392	3	2655	80	392	3	2655	80	392	3	2655	80	392
TOTAL CENT. COMP. REQ'MTS	9790	157	110	2	15925	160	110	1	24355	159	180	2	19655	159	180
TOTAL CENT. COMP EXEC TIME				269				271				341			
TOTAL CC 32 BIT**	9790			350	15925			352	24355			443	19655		
TOTAL CC 24 BIT**	10769		355		17218		355		26490		449		21540		449
TOTAL CC 16 BIT**	11748	666			18311	665			28926	956			23526	956	
RENDEZVOUS & DOCKING															
MISSION CONTROL									700				700		
REND GUIDANCE	475				725				1100				1100		
TOTAL CC SOFTWARE WITH REND & DOCKING - 32 BIT	10265				16650				25155				21655		
RDP EXEC TIME 16 BIT**		1730				1730				1730				1730	

Δ ATTITUDE UPDATE (IMU) PERFORMED IN RDP 1365 (40/225/1) ALL AUTONOMY LEVELS
POS/VEL DET - IMU PERFORMED IN RDP 1290 (40/167/2) ALL AUTONOMY LEVELS

*FIXED POINT; NO HALF WORD CAPABILITY; 2μ SEC ADD; 32 BIT WORD LENGTH (TOTAL CENTRAL COMPUTER & RDP REQ'MTS)
**FIXED POINT; NO HALF WORD CAPABILITY; 2,6μ SEC ADD; 22μ SEC DOUBLE PRECISION ADD; 75μ SEC DOUBLE PRECISION MULTIPLY

Guidance Navigation and Control (GNC) Subsystem

A change in autonomy from III to IV has no impact on the GNC. Increasing autonomy to level I or II requires the addition of a horizon sensor to perform the autonomous navigation function. Because of the more frequent stellar updates required for the autonomous navigation, a gimballed star tracker is recommended for autonomy levels I & II. The sensitivities are summarized below:

END ITEM	DDT&E (M$)	WEIGHT (LB)	POWER (WATTS)
Horizon Sensor	2.54	10	17
Gimballed Star Tracker	2.02	60	60
	4.56	70	77

Communication Subsystem

Autonomy levels I and II require additional communication equipment for payload checkout. This capability is provided by both hardwire and an RF link to the payload. The latter capability is requested to checkout portions of the payload equipment which can not be accomplished while the payload is attached to the Tug. A summary of the communication subsystem impacts are summarized below. There is no communication sensitivities associated with autonomy level IV.

END ITEM	DDT&E (M$)	WEIGHT (LB)	POWER (WATTS)
Payload Interrogator	4.79	37	22

Power Subsystem

The added power requirements for autonomy levels I and II are summarized below.

Subsystem	End Item	Power (Watts)
DMS	2 Computers	156
GNC	Horizon Sensor	10
GNC	2 Gimballed Star Trackers (in place of 2 strapdown)	60
Comm	Payload Interrogation Equipment	22

The weight increase to accommodate this power increase is 49.5 lb which includes reactants and tankage. Cost increase is negligible.

12.4.3 Weights and Performance

The increase in vehicle weight and decrease in payload deployment associated with autonomy levels I and II is summarized below. There is no significant weight penalty associated with autonomy level III.

Subsystem	End Item	Vehicle Weight Increase (Lb)	Deployment Weight Decrease (Lb)
DMS	Computer	32	86.4
DMS	DIU	8	21.6
GNC	Horizon Sensor	17	45.9
GNC	Gimballed Star Tracker	60	162.0
COMM	Payload Interrogation Equipment	37	99.0
PWR	Reactants & Tankage	49.5	133.65
		203.5	548.55

12.4.4 Operations Variations

Ground Operations

An increase to Autonomy Level IV results in a decrease in GSE software to checkout the Data Management Subsystem. There are no hardware impacts. For the higher autonomy levels (I and II) additional hardware is required to checkout the horizon sensors used for autonomy navigation. In all cases, the change in ground operations cost is negligible.

All system testing is accomplished via the Data Management system. The computer time to test the additional hardware is negligible and has little or no impact on launch operations. Our system and subsystem testing are go/no-go type tests. The launch operations are sized to handle the Tug/Orbiter functions in the time allocated for that function drive the number of personnel required at the launch site. The higher autonomy has little or no impact on launch operations since the launch personnel is available at the launch site. The autonomy cost sensitivities are summarized below.

	AUTONOMY LEVEL		
	IV	II	I
DDT&E (M$)			
SOFTWARE	-0.71	1.41	0.57
HARDWARE	0.0	.22	.22
OPERATIONS	Neg	Neg	Neg
	-0.71	1.63	0.79

AUTONOMY SENSITIVITIES

FLIGHT OPERATIONS COSTS

OPTION 3

Flight operations costs were determined for each of the four autonomy levels ranging from I to IV. As shown in Table I, the autonomy levels are arranged in increasing order of autonomy going from IV to II. The autonomy level II was considered the most autonomous of the four levels investigated. The flight operations costs were divided in accordance with the WBS Breakdown into recurring costs (Operations Cost 32C) and non-recurring costs (DDT&E Cost 32A) for each of the four fight operations tasks of Mission Planning (WBS 320-11/12-01), Flight Control (WBS 320-11/12-02), Flight Evaluation (WBS 320-11/12-03), and Flight Support Software (320-11/12-04).

An additional item not included in the WBS Breakdown called unused time is also shown in Table I. This item indicates the cost for unused manhours resulting from keeping a full mission control crew at both a NASA and a DOD mission control center. These unused manhours decrease with increasing autonomy level because a smaller crew is required for higher autonomous vehicles.

As can be seen from the cost data of Table I the more autonomous the vehicle is the higher the non-recurring (DDT&E) costs. Also, it is shown that for the higher autonomous vehicles the recurring (Operations) costs decrease. The delta (Δ) costs shown in Table 12.4-4 were determined using the present Option 3 vehicle autonomy level of III as a reference. Autonomy level IV gives the lowest Flight Operations costs.

Table 12.4-2

OPTION 3

AUTONOMY SENSITIVITIES

FLIGHT OPERATIONS COSTS

TOTAL MISSIONS

	AUTONOMY LEVELS			
	IV	III	II	I
RECURRING COSTS (M)	95.35	91.87	90.71	90.71
MISSION PLANNING	17.17	19.02	22.50	20.88
FLIGHT CONTROL	47.56	42.67	38.16	39.79
FLIGHT EVALUATION	20.18	20.19	20.18	20.18
FLIGHT SUPPORT SOFTWARE	10.44	9.98	9.86	9.86
OPERATIONS PER FLIGHT (K)	263	254	251	251
NON RECURRING COSTS (M)	13.72	20.59	25.13	22.91
MISSION PLANNING	6.31	12.73	17.27	15.06
FLIGHT CONTROL	1.00	1.55	1.55	1.55
FLIGHT EVALUATION	0	0	0	0
FLIGHT SUPPORT SOFTWARE	6.53	6.31	6.31	6.31
UNUSED TIME (M)	8.52	6.86	6.86	6.86
Δ RECURRING COSTS (M)	3.48	0	-1.16	-1.16
Δ NON RECURRING COSTS (M)	-6.87	0	4.54	2.32
Δ FLIGHT OPERATIONS COSTS (M)	-3.39	0	3.38	1.16

Since Option 3 is a phased program an autonomy IV vehicle was used for the initial phase of the program and the final vehicle autonomy was varied from IV to II. For the case of when an autonomy level IV is used for the final vehicle the program does not have the 1.7 costs factor for phasing from one configuration to another. Therefore, since an autonomy level IV initial vehicle does not require additional DDT&E costs for phasing it becomes the lowest cost configuration.

It is also obvious from the data given in Table I that had the higher autonomy level final vehicles not used a phasing program the savings in both DDT&E and Operations, costs would have shown that the higher autonomy level vehicles to have much lower Flight Operations costs than the autonomy level IV vehicle.

12.5 Onboard/Shuttle Checkout Tradeoffs

The issue to be discussed in this section is the distribution of checkout functions between the Tug/Shuttle when the Tug is in the payload bay. It is currently envisioned that the Tug will be partially operational during the boost phase. The DMS will be performing the initial navigation calculation as well as monitoring subsystem status. Telemetry data will be accessed by the DMS and transmitted to the Shuttle.

The navigation optical sensors, rendezvous/docking sensors, communication transponders, and power sources will not be active during boost.

The vehicle control software will contain the fault detection/isolation logic required to manage the subsystem redundancies, therefore the portion of the Tug that is operational will be checked out in the normal process of control. As an example the DMS computer will be periodically executing computer diagnostics as part of its normal control cycle. Prior to leaving the payload bay a subset of the following checkout functions could conceivably be performed.

1) Checkout of the non-active Tug LRU's (i.e., star tracker, transponders, etc.)
2) LRU level fault isolation. This level of fault isolation is not always required during the mission.

The checkout of the non-active LRU's could be accomplished by executing Shuttle resident checkout programs, normal Tug control software, or Tug resident checkout programs.

The following general Tug/Shuttle operating concepts are recommended:

1) Tug checkout will be accomplished by executing the normal Tug control software.
2) The Tug control software will perform fault detection but will normally only isolate to the level at which the redundant elements can be switched.

(NOTE: In some cases it may prove advantageous to isolate to a lower level in order to increase the confidence level of isolating a failure or to simplify the software required.)

3) The results of the Tug software fault detection/isolation algorithms will be transmitted on the downlink.

4) Subsystem performance data will also be transmitted on the downlink.

5) The Shuttle will have access to the Tug TM data and can evaluate the Tug performance based on both a software and operation interrogation of this data

6) The Shuttle can exercise the normal uplink control over the Tug software.

7) Checkout routine other than those required for subsystem control will be carried in the Shuttle and executed via the proposed 1 MH_z Shuttle/Tug interface. This interface would provide the Shuttle with parallel access to the Tug command/control busses and therefore must be closely controlled. The need for this level of checkout is still somewhat undefined at this time and needs further investigation. This capability is a candidate for phasing.

In summary it would appear that the majority, if not all of the required Tug checkout software will be incorporated in the normal control software and that the Shuttle will primarily monitor the Tug operation and exercise uplink control.

12.6 Dump Versus Land Full Abort

This trade study will address the features, characteristics, benefits, and liabilities of the major choices to dump any or all of Tug cryogens versus the choice to dump no Tug cryogens and to design the Tug to contain the cryogens through a normal landing. The key basis of comparison will be the payload weight penalty, including the fractional weight reduction impact on payload capability from added Orbiter weight on either a geo-synchronous deployment mission or on a round-trip mission. The payload weight penalties will be assessed against a hypothetical Tug design lacking any abort provisions. The weight differentuals or "deltas" will then be available to compare these options. The suborbital abort mode III is used as reference for this study due to the greater time constraints and greater significance in terms of design impacts. Thus, a Tug designed to meet Suborbital Mode III abort constraints will meet all abort conditions, if the porting provisions for orbital thrust-settled cryogen release are also provided.

The weight comparison resulting from this study and some key conclusions and recommendations are shown in Table 12.6-1. The compelling conclusions which lead to the selection of LO_2 dumping only are a payload weight reduction penalty of 1,526 lb for land full, 449 lb for sequential dump of LO_2 and LH_2, and 414 lb for simultaneous dumping of LO_2 and LH_2.

In addition, the land full option, although is the most simple in terms of flight operations, (1) imposes an unacceptable CG incompatibility for stable aerodynamic flight and landing, (2) imposes serious safety questions during return flight, landing and post-landing operations, and a major landing abnormality or impact could seriously threaten the structural integrity and result in ground safety hazards with both LH_2 and LO_2 on board.

TABLE 12.6-1

ABORT STUDY ASSESSMENT

	LAND FULL	DUMP CRYOGENS		
		LO_2 ONLY	LO_2 AND LH_2	
		3 IN. LINE	SEQUENTIAL 3.5 IN. & 5 IN.	SIMULTANEOUS 3 IN. & 5 IN.
Δ TUG WEIGHT (LB)	+806	+144	+177	+164
Δ ORBITER WEIGHT (LB)*	+94	+340	+1303	+1297
Δ PAYLOAD WEIGHT (LB)				
ROUND TRIP**	-815	-178	-307	-294
GEOSYNCH DEPLOY***	-2015	-489	-938	-903

LAUNCH FULL, LAND FULL

- SAFETY ASPECTS QUESTIONABLE
- CANNOT ACCOMMODATE CRASH LOAD FACTORS (ABORT AND CRASH LANDING ARE NOT CONCURRENT CONDITIONS FOR THIS STUDY)
- LANDING CG OUTSIDE OF JSC 07700 PROFILE RANGE

DUMP SYSTEMS

- SUBORBITAL DUMP IN MODE III ABORT (T +116 SEC OR LATER)
- SIMULTANEOUS LH_2 DUMP AND LO_2 DUMP DEPENDS ON TIME AVAILABLE ABOVE 110K FT
- SEQUENTIAL DUMP IS PREFERRED WHEN TIME AVAILABLE, FOR SAFETY MARGIN
- SIMULTANEOUS DUMP SAFETY DEPENDS ON ATMOSPHERE PRESSURE AND OUTLET PORT SEPARATION
- PAYLOAD WEIGHT IMPACT & CG BENEFIT CONTRIBUTE TO LO_2 DUMP PREFERENCE

RECOMMENDATION: LO_2 DUMP

* INCLUDES ANCILLARY EQUIPMENT

** $\Delta W_{PL} = -[\Delta W_{TUG} + 0.1 (\Delta W_{ORBITER})]$ FOR ROUND TRIP

*** $\Delta W_{PL} = -[\Delta W_{TUG} \times 2.5 + 0.38 (\Delta W_{ORBITER})]$ FOR DEPLOY TO GEOSYNCH ORBIT

The return of LH_2 alone in a pressure-vent-limited tank is considered an acceptable ground safety risk for normal landing and the landing weight is very low with LH_2 on board. The Orbiter would be heavier by 43,000 lb or more for a land-full condition. Moderately high landing g-forces or minor impacts would not necessarily threaten Tug structural integrity nor ground crew safety. The remaining risks of LH_2 return are balanced against the probability of a suborbital abort versus the larger possibility of an orbital abort, for which LH_2 dumping either with or without Helium purging is planned. The final argument is that containment of LH_2 at reduced pressure (18 psia or less) is an inherently simpler and safer mode of operation then the more complex and constrained mode of LH_2 dumping below 400,000 ft in a fast return to launch site.

Option 1 - Dump LO_2 Only and Retain All of LH_2

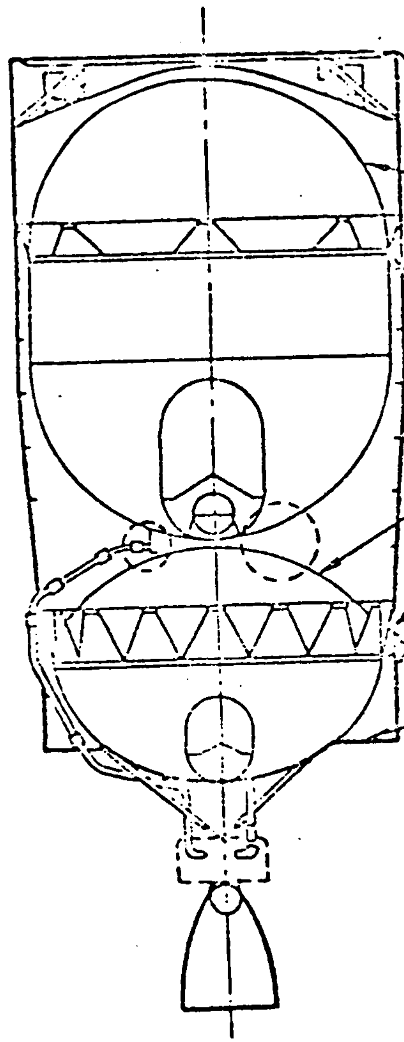
This is the selected mode of operation, and is described in detail in Volume 5, Sections 5.2.4.5 and 5.4. The time available for LO_2 dump is much greater than required and can be initiated at any time after the abort decision is made. Thus, the least time available is from T+251 to landing at T+1,241, less 60 sec during MECO and ET jettison, or 930 sec. The benefits of early dumping in terms of 43,000 lb of potential weight reduction and the resulting increase of Shuttle ΔV were discussed in Section 6.4. A ΔV increase of 1.7% in an early abort (T+115) or 0.4% in a late abort (T+251) are appreciable in terms of proportionally extending the orbit-to-orbit thrust margin. It is also necessary to dump at least 20% of the LO_2 before external tank jettison and return to aerodynamic flight, due to CG constraints. Therefore, LO_2 dumping should be initiated immediately after an abort decision is made.

Option 2 - Land Full - No Cryogen Dumping

The primary factors for and against a land-full option were summarized above, and the additional weight data is provided in Figure 12.6-2 in support of the summary chart, Table 12.6-1, above. The weight impacts are chiefly the result of "beefing up" the Tug tank and supporting Tug structure, with additional weight for horizontal fill and drain provisions for the LO_2 tank.

The CG incompatibility for return flight and landing is a compelling factor against a land-full option. A heavy payload or off-loading of the LO_2 tank would be necessary to restore compatibility, but this would prevent accomplishment of the round-trip and retrieval missions, and is therefore unacceptable.

LAND FULL ABORT
(STRUCTURAL PENALTY)



	Δ WEIGHT (LB)
FWD SUPT FRAME AND FTGS	66
LH_2 TANK	0
LH_2 TANK SUPTS	10
LH_2 TANK SUPT RING	12
STRUCTURAL SHELL	370
LO_2 TANK	185
LO_2 TANK SUPTS	33
LO_2 TANK SUPT RING	8
AFT ATTACH FTGS	2
	+686

- LANDING LOAD FACTORS CONTROL
- SAFETY FACTOR = 1.4

Figure 12.6-2

Option 3 - Dump Both LO_2 and LH_2

Two sub-options for LO_2 and LH_2 dumping in a suborbital abort were identified and discussed briefly in Volume 5, Section 2.4.5 with respect to the LH_2 cryogen handling options listed in Table 12.6-1. These are Option 3A - Sequential Dumping of LO_2 and LH_2 and Option 3B - Simultaneous Dumping of LO_2 and LH_2. The sequential dump option is the more difficult and the required analytic data also provides for the simultaneous dump option. Both options will be discussed and conclusions will be drawn for comparison. The payload weight penalties will be developed and summarized with the Dump LO_2 only and the Land Full options.

Option 3A - Sequential Dumping of LO_2 and LH_2

Sequential dumping of both LO_2 and LH_2 is most severely constrained by the time available from the late abort decision (T+251) to 30 seconds prior to Main Engine Cut off (MECO) and from 30 seconds after MECO until 110K ft altitude is reached, where LH_2 dump termination is mandatory. This most constrained case will be addressed to produce the abort hardware requirement for all Tug designs. The abort trajectory which applies to the late Mode III abort case is shown in Figure 12.6-1. The pertinent data is listed in Table 12.6-2.

Table 12.6-2

MISSION ABORT DATA

Mode III Abort - Suborbital

Easterly Mission with 65K lb total for Tug/Payload

Late Abort Decision

All events occur below 400K ft in sensible atmosphere

Abort Start: T+251

Dump Initiation: T+251

Dump Termination: T+530.9

Available Dump Time: 279.9 seconds (main engine operating)

MEBO, ET Jettison: T+560.9

Dump Initiation: T+590.9

LH_2 Dump Termination (110K ft): T+726 or earlier

Flight Altitude of 50K ft: T+986

Landing: T+1241

Available Dump Time $<$135 seconds for LH_2 during glide

Available Dump Time: 650 seconds for LO_2 or 515 seconds after LH_2 Dump Termination

LW ORBITER ASCENT ABORT MODE III -- ALTITUDE-VELOCITY PROFILE

- EASTERLY MISSION
- INPLANE MANEUVER
- T_{ABORT} = 251 SEC
- LOSS OF ONE MAIN ENGINE
- 2 MAIN ENGINES AT 109% EPL
- NO WINDS

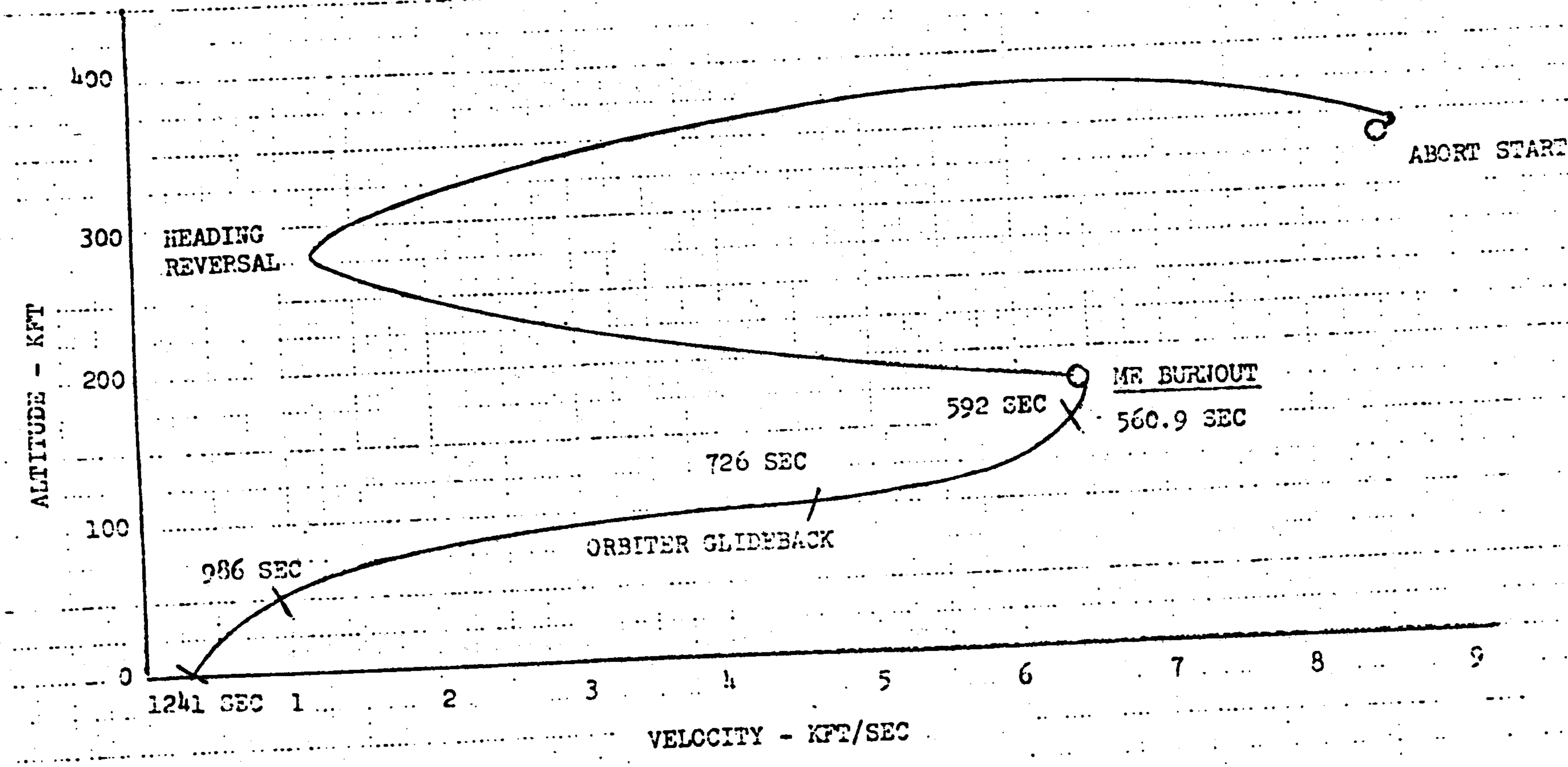


Figure 12.6-1

Applying these time constraints to the data in Figures 12-2, -3, and -4, the dump line size requirements are derived and listed in Table 12.6-3.

Table 12.6-3

DUMP-LINE SIZE REQUIREMENTS

Time 100% Dump	Tug Option	LO_2	LH_2
135 Sec	1	5.4 Inch	4.7 Inch
	2	5.9	5.0
	3I	5.4	4.7
	3F	5.6	4.9
280 Sec	1	3.9	3.4
	2	4.3	3.7
	3I	3.9	3.4
	3F	4.0	3.5
515 Sec	1	3.0	2.6
	2	3.3	2.8
	3I	3.0	2.6
	3F	3.1	2.7
650 Sec	1	2.7	2.4
	2	3.0	2.5
	3I	2.7	2.4
	3F	2.8	2.5

Liquid oxygen can be dumped for a longer time than LH_2, essentially down almost to landing, and a 3.0-inch line spans all Tug options. Assume a 3-inch LO_2 abort line is selected:

Tug Option	Time 100% Dump (LO_2)
1	505 Seconds
2	635
3I	505
3F	530

From the late Mode III abort trajectory, the duration of Main Engine operation is 280 seconds. With a 3-inch LO_2 dump line, we can dump 280/635 = 44.1% of LO_2.

NOTE: Unporting need not occur to 50% of LO_2 dump, depending on

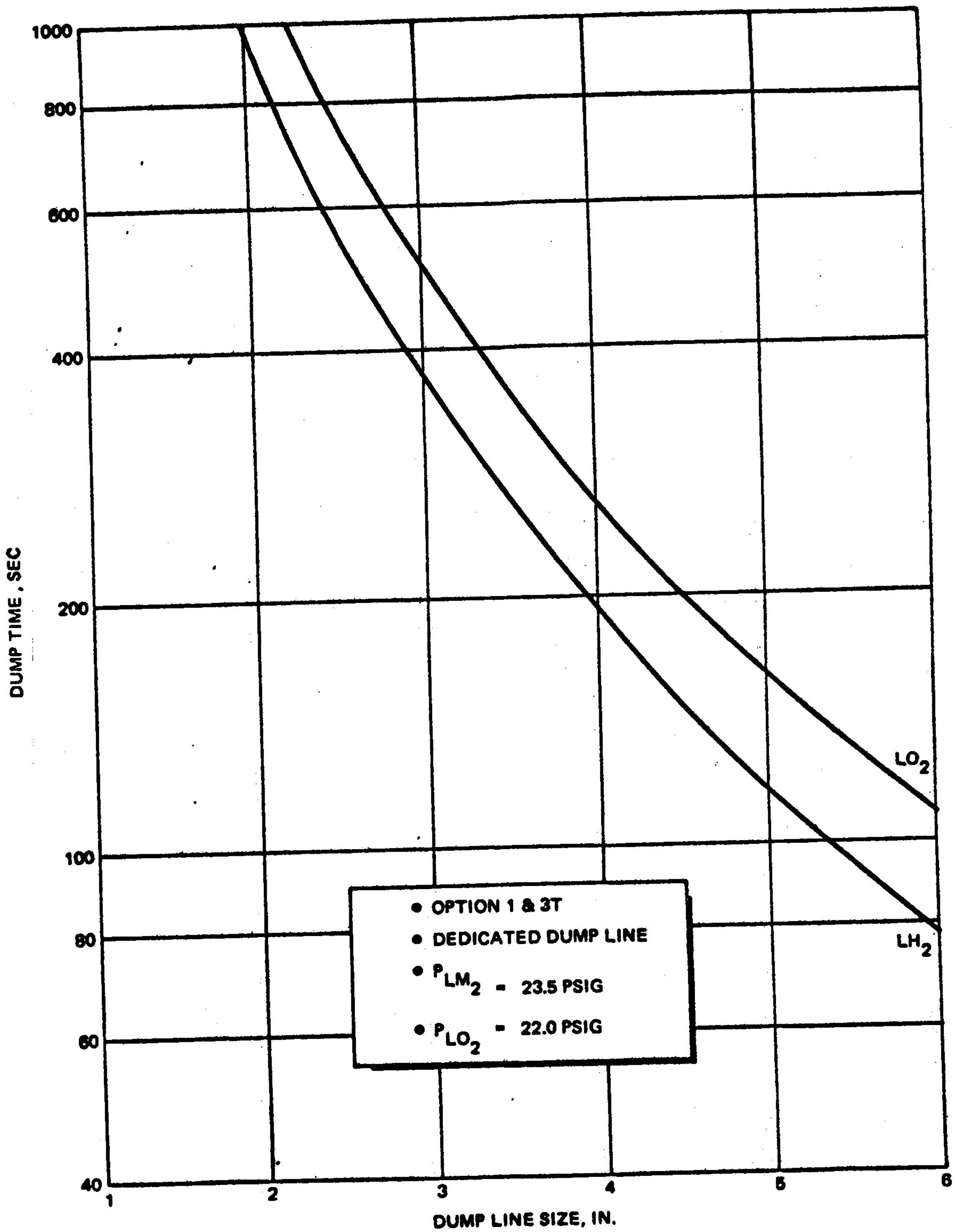

1000
800
600
400
200
100
80
60
40
DUMP TIME, SEC
1
2
3
4
5
6
DUMP LINE SIZE, IN.
LO_2
LH_2
• OPTION 1 & 3T
• DEDICATED DUMP LINE
• P_{LM_2} = 23.5 PSIG
• P_{LO_2} = 22.0 PSIG

Figure 12.6-2

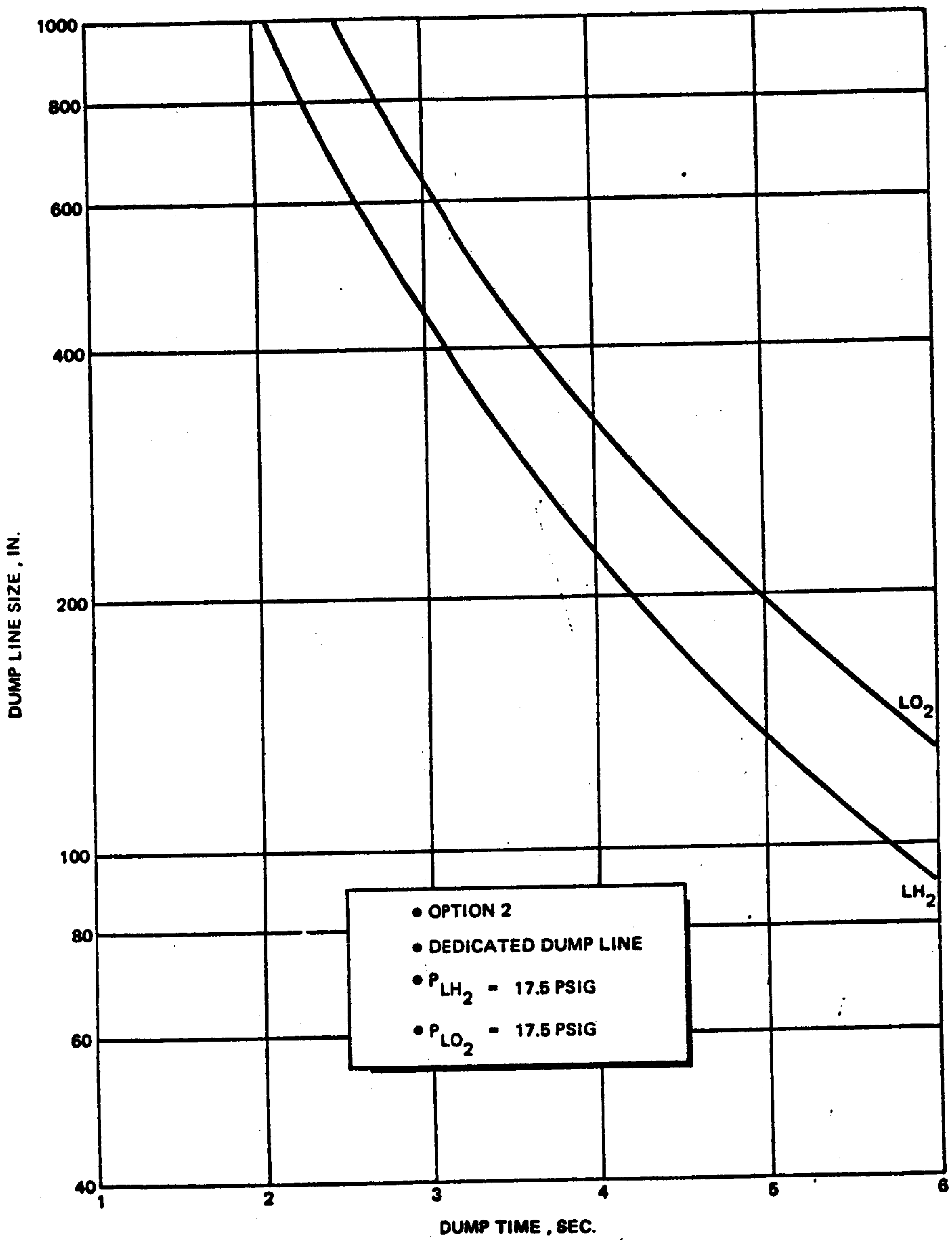

1000
800
600
400
200
100
80
60
40
DUMP LINE SIZE , IN.
1
2
3
4
5
6
DUMP TIME , SEC.
LO2
LH2
• OPTION 2
• DEDICATED DUMP LINE
• P LH2 = 17.5 PSIG
• P LO2 = 17.5 PSIG

Figure 12.6-3.

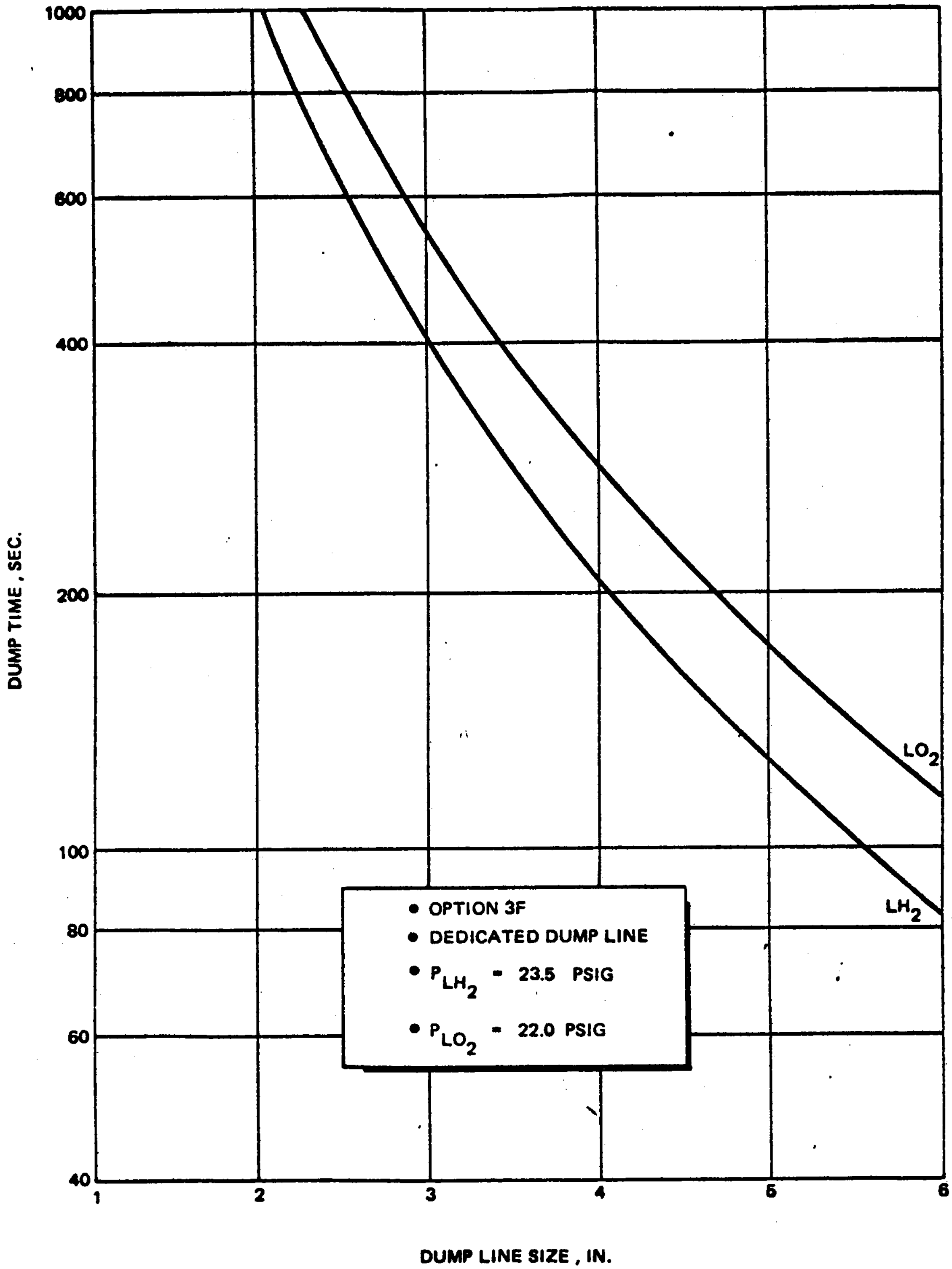
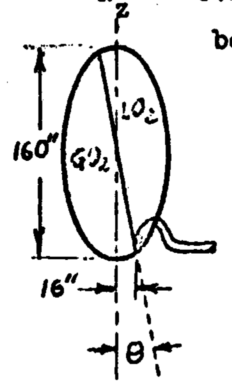
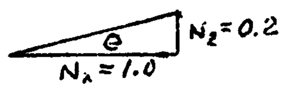

DUMP TIME , SEC.
1000
800
600
400
200
100
80
60
40
1
2
3
4
5
6
DUMP LINE SIZE , IN.
LO2
LH2
• OPTION 3F
• DEDICATED DUMP LINE
• P LH2 = 23.5 PSIG
• P LO2 = 22.0 PSIG

Figure 12.6-4.

the 3-inch abort line port location and the +Z g-force during thrust and heading reversal. The g-force trajectory profile is shown in Figure 12.6-5. The greatest tilt of the gas/liquid interface occurs at the start of abort with N_x = +1 and N_z = +0.2. Tan θ = 11.4°. then the LO_2 abort line port must be more than 16 inches aft of the side centerline to prevent unporting at 50% dump. Actually, the situation is a little worse due to 5% ullage gas volume at start of mission, placing the 50% LO_2 vertical line aft of the center-line. Thus, assume 40% dump as a cutoff point at 40% x 635 = 254 sec.





635-254 = 381 seconds remain necessary to dump 100% of LO_2. The 20% minimum dump of LO_2 necessary for CG control has thus been greatly exceeded before engine burnout. Either LH_2 or LO_2 can be dumped now.

Assume that LH_2 is dumped, according to the sequential dump alternative study option. To obtain 100% LH_2 dump in 135 seconds down to 110K ft will require a 5.0-inch line. The 381 seconds for subsequent dumping of LO_2 to depletion can occur from T+726 to T+1107, terminating at about 25K ft altitude.

Line-Optimized Option 3A - Sequential LO_2 and LH_2 Dumping

The following analysis is based on the round-trip mission loading data for Option 1. If LO_2 is initially dumped in a late (T+251) Mode III abort to achieve an acceptable CG profile, about 20% or less of LO_2 must be dumped. This requires 20% x 635 = 127 sec through a 3-inch LO_2 abort dump line, leaving 635 - 127 = 508 seconds for glide period dumping of LO_2. LH_2 dumping can occur for 280 - 127 = 153 seconds during engine thrusting. This is $\frac{153}{1150}$ = 13.3% for 2-inch, $\frac{153}{435}$ = 35.2% for 3-inch, $\frac{153}{230}$ = 66.5% for 4-inch, or $\frac{153}{135} > 100\%$ for 5-inch LH_2 abort line.

ORBITER ASCENT ABORT MODE III LOAD FACTOR

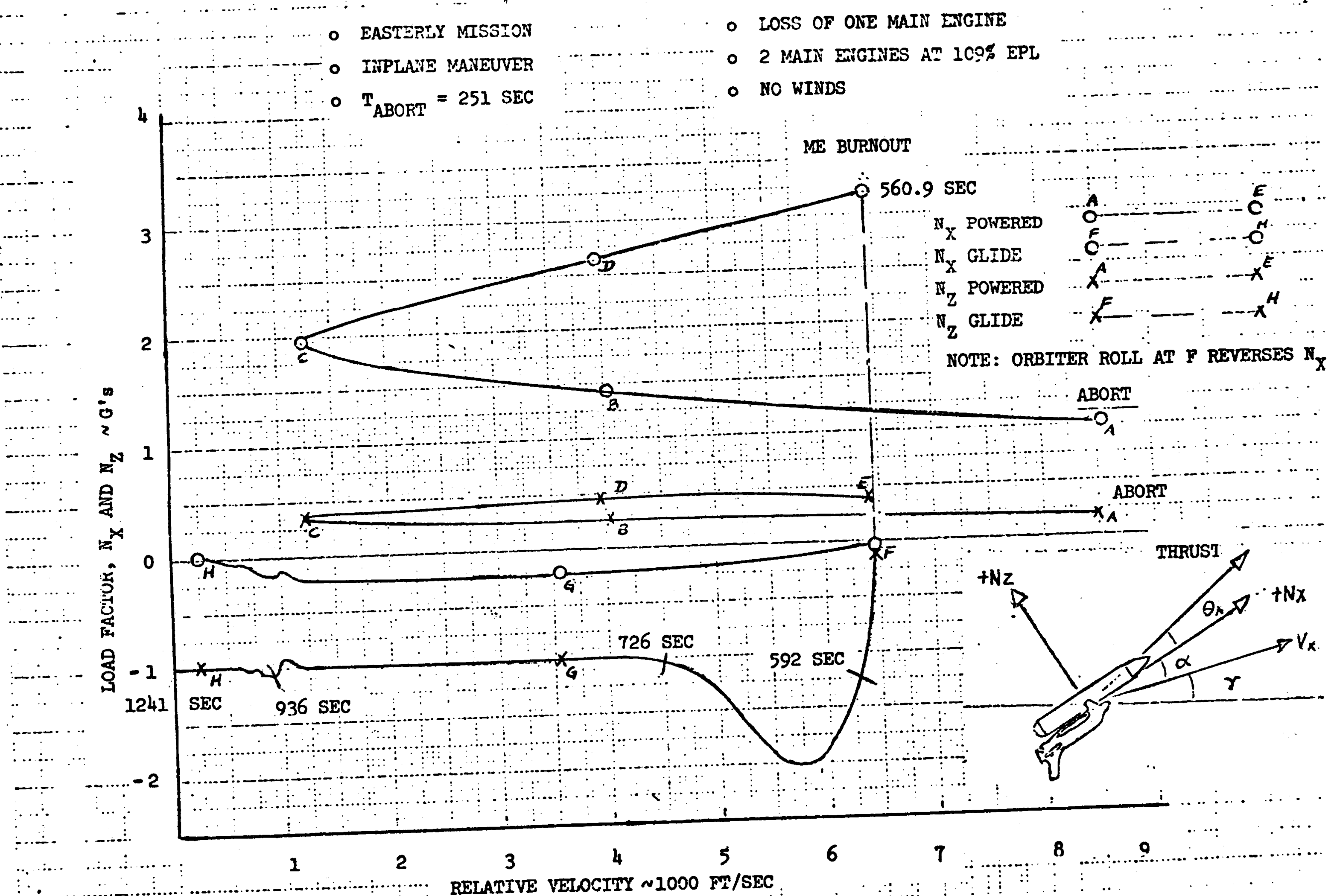


Figure 12.6-6

The glide period of 135 seconds would allow

$\frac{135}{1150}$ = 11.7% for 2-inch,

$\frac{135}{435}$ = 31.0% for 3-inch,

$\frac{135}{230}$ = 58.7% for 4-inch, and

$\frac{135}{135}$ = 100% for 5-inch line sizes

Therefore, the following composite of LH_2 dump is obtained:

Line Size	Thrust Period	Glide Period	Total
2-inch	13.3%	11.7%	25.0%
3	35.2%	31.0%	66.2%
4	66.5%	58.7%	125.2%
5	>100%	100%	> 200%

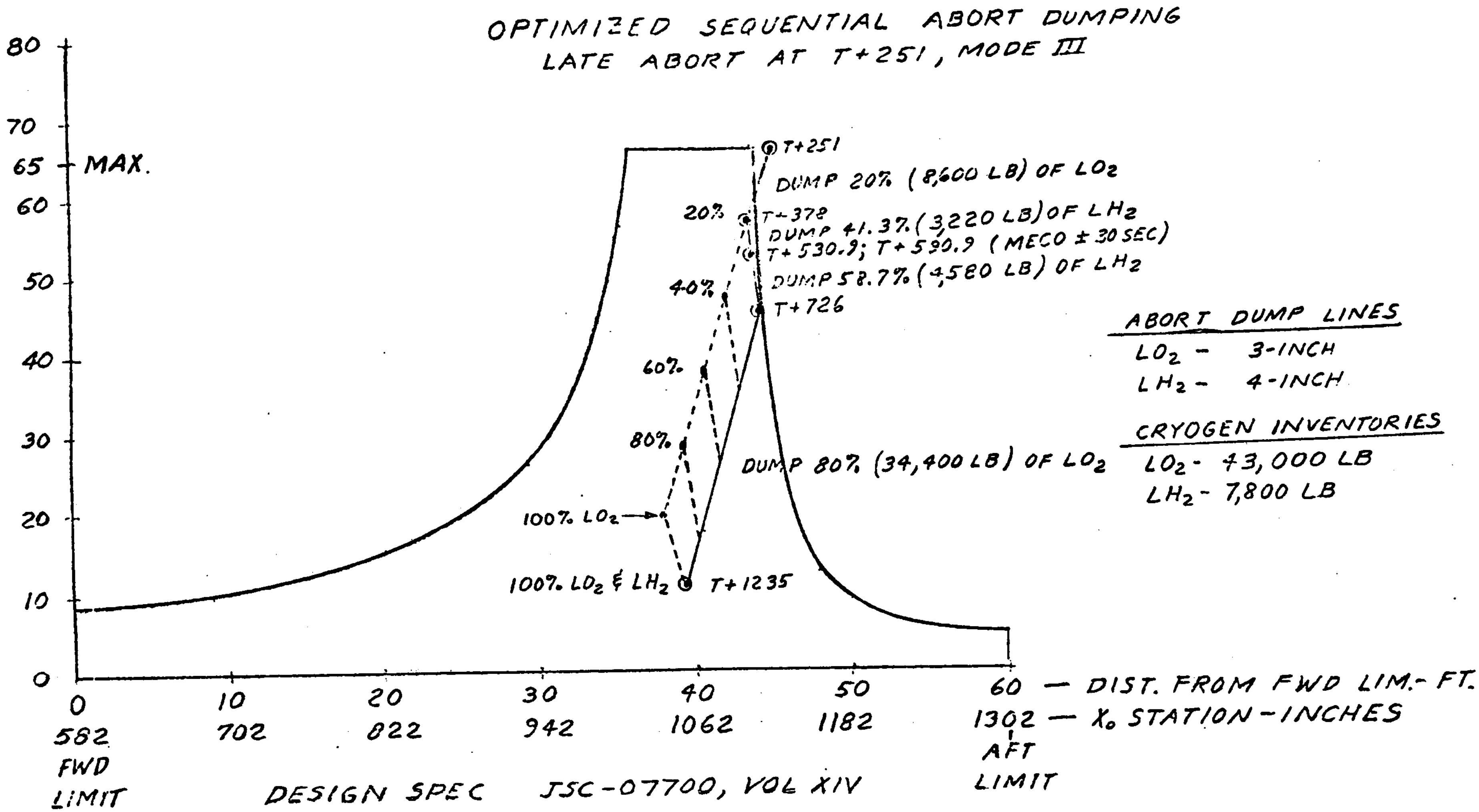
The proper size for 100% dumping is less than 4-inch for the LH_2 abort dump line. Following the same side port location analysis as for LO_2, if 41.3% of LH_2 is dumped during engine thrust through a 4-inch line, the remaining 58.7% can be dumped during glide to 110K ft.

The abort dumping time-line sequence then is as follows:

Abort Start: T+251
LO_2 Dump Start: T+251
LO_2 Dump Terminate: T+378 (20%)
LH_2 Dump Start: T+379
LH_2 Term: T+530.9 (41.3%)
LH_2 Dump Start: T+590.9
LH_2 Dump Term: T+726 (100%)
LO_2 Dump Start: T+727
LO_2 Dump Term: T+1235 (100%)
Landing: T+1241

9

This abort profile is shown on Figure 12.6-6 for the worst-case condition -- late Mode III abort at T+251 with 50,800 lb of cryogens for a normal round-trip mission.



PAYLOAD LONGITUDINAL CG ENVELOPE

Figure 12.6-5

An early mode III abort at T+116 would permit 135 seconds more of initial LO_2 dumping, to a limit of 44.1% of LO_2 dumped. There is a family of options in this case within the design window defined by dashed lines on Figure 6.12.6-6, from 20% to 44.1% of initial LO_2 dump, followed by alternative dumping of LH_2, followed by LO_2 until MECO - 30 sec; then depletion of LH_2 well above the 110K ft altitude, and finally LO_2 depletion at about T+1100 sec.

Conclusions

Two designs for sequential dumping of both LO_2 (normal) and LH_2 (optional) have been determined. Operational profiles for each have been defined to meet the constraints of CG compatibility, altitude, available time, and selected line size.

Option 3a-1 - For LH_2 dumping only during glide return, preceded by up to 40% of LO_2 dump and followed by LO_2 depletion; a 5-inch LH_2 line would be provided in the LH_2 tank side location. A 3-inch LO_2 line would also be provided in the LO_2 tank side location.

Option 3a-2 - For minimum LH_2 dump line sizing, LH_2 dumping (41.3%) would precede MECO - 30 seconds, and LH_2 depletion would follow MECO + 30 seconds down to 110K ft altitude. This requires a 4-inch LH_2 line, and the 3-inch LO_2 line permits a 20% LO_2 dump before the pre-MECO dump. It allows LO_2 depletion subsequent to LH_2 depletion, ending at 25K ft altitude or higher.

Option 3b - A Simultaneous LO_2 and LH_2 Dumping

While simultaneous dumping of both LO_2 and LH_2 have not been discussed in detail, it obviously is less constraining upon line size. Simultaneous dump operations can be inferred from the least time available on a late Mode III abort, which is 530.9 - 251 = 279.9 seconds pre-(MECO - 30 sec) and 726 - 590.9 = 135.1 seconds post-(MECO + 30 sec). Thus 415 seconds are available for LH_2 dumping, which requires a 3.07-inch line diameter for depletion. The nominal 3-inch LO_2 line will provide up to 44.1% LO_2 dump prior to MECO - 30 sec and adequately provides CG compatibility before MECO.

A key constraint is imposed on simultaneous dumping by the presence of sensible atmosphere below a 400K ft altitude. The atmosphere produces a "wake" effect that may draw released cryogens back into the engine and boat-tail region and may thus produce a potential hazard as greater atmospheric pressure develops and ignition sources or static discharge may be present. Adequate separation of LO_2 and LH_2 abort line exits and injection of dumped cryogens well into the "slip-stream" should minimize this potential hazard down to 110K ft altitude.

12.7 Other Sensitivities

Cryogenic Versus Storable Propellant ACPS Ground Operations

An analysis was performed to determine the effects on Option 3 ground operations which would result from utilizing a cryogenic attitude control system, rather than the baselined storable propellant systems. The impacts were investigated in the following four areas:

1. Maintenance and Refurbishment
2. Ground Support Equipment
3. Ground Operations Crew Size
4. Ground Turnaround Time

The analysis shows that a configuration change for Option 3 vehicles to a cryogenic ACPS would result in an operations cost increase of nearly $1 million. In addition, this revision to the baselined configurations would increase the total program cost by nearly $17 million.

Maintenance and Refurbishment

Option 3I utilizes a storable monopropellant ACPS, while Option 3F utilizes a storable bipropellant ACPS. The Option 3I configuration accomplishes 133 flights with four vehicles (33.3 flights per vehicle). The Option 3F configuration accomplishes 239 flights with eight vehicles (29.9 flights per vehicle). Scheduled maintenance and refurbishment costs for the baselined systems amounts to a total of $76,000 (eight refurbishments at $9,500 each, as shown in Table 6.12.7-1).

Utilizing the cryogenic ACPS in both the initial and final configurations results in the following scheduled ACPS maintenance and refurbishment operations.

Initial

Four refurbishments required = $790,000

Final

Eight refurbishments required = $1,580,000

The total program scheduled maintenance and refurbishment costs would therefore be increased a total of $2,294,000 if the cryogenic ACPS was utilized during the Option 3 program.

Table 6.12.7-1

ACPS REFURBISHMENT CHARACTERISTICS – STORABLE VS CRYOGENIC

ACPS Candidates	Service Life	Operating Time per Mission	Refurbishment Criteria	Missions before Scheduled Refurbishment	Scheduled Refurbishments per No. of Reuses		
					20	50	100
• Mono-Propellant - 25 lb Thrust	Indefinite	340 sec	4K sec	12	1	4	8
• Cryogenic - 25 lb Thrust	Indefinite	340 sec	9K sec	26	0	1	3

Note:

Refurbishment Criteria for Cryogenic ACPS was estimated at 50 percent of the operating life of a Category I RL-10 Main Engine before refurbishment. The RL-10 and the Cryogenic ACPS have similar components and wear life.

ACPS REFURBISHMENT COSTS – STORABLE VS. CRYOGENIC

ACPS Candidates	Average Production Unit Cost $ K	Refurbishment as a % of Average Production Unit Cost	Cost per Refurbishment $ K	Missions before Scheduled Refurbishment	Scheduled Refurbishment Costs Per No. of Uses $ K		
					20	50	100
• Mono-Propellant - 25 Lb Thrust	861	1.1%	9.5 (1)	12	9.5	38	76
• Cryogenic - 25 Lb Thrust	1316.6	15%	197.5 (2)	26	-	197.5	592.5

Notes:

(1) Mono-Propellant ACPS refurbishment costs include only four axial (aft firing) thrusters.

(2) Cryogenic ACPS refurbishment costs include only the two primary turbomachinery/gas generator packages.

12-46

Ground Support Equipment

The following list itemizes the changes to the ground support equipment which would result from incorporating a cryogenic ACPS in the Options 3I and 3F configurations:

Item No.	Title	Program Cost Delta 3I	Program Cost Delta 3F
112	ACPS Loading Kit	- $ 7,000	0
113	ACPS Servicer	- $ 5,000	- $4,800
117	C/O Accessory Kit	- $ 6,000	0
139	Gas Sampling Kit	- $ 300	0
152	Protection Equipment	- $ 32,000	0
153	ACPS Test Set	- $160,000	0
191	Workstands	- $ 24,000	0
	Total Impact	- $234,300	- $4,800

Ground Operations Crew Size

The present baselined systems require transport of the Tug vehicles to the Storable Propellant Areas (at KSC and VAFB) for both post-flight safing and prelaunch servicing. The incorporation of a cryogenic ACPS in Options 3I and 3F will have three impacts on the ground crew size. First, the additional activities associated with loading at the launch pad and safing at the Shuttle Safing Area will increase the program required total ground crew (ETR plus WTR) by a total of 12 personnel. Second, during the 3I configuration ground turnaround cycles, the activities required at the Storable Propellant Facility would be eliminated. This would reduce the manpower required during these shifts of operations by a total of 24 people. Third, during the 3F configuration ground turnaround cycles, the activities originally required at the Storable Propellant Facility would be eliminated. This would reduce the manpower required during these shifts of operations by a total of 32 people.

The net effect on the ground crew sizing, analyzing the task sharing and shift manloading, would amount to two crewmen at KSC and one crewman at WTR during the first four years and one year, respectively. As Option 3F is introduced into the program at the fifth year, the net effect would amount to three crewmen at KSC and two crewmen at VAFB, during the final seven years of the program. This equates to a cost savings of approximately $1,100,000.

Ground Turnaround Time

The average ground turnaround times for the Option 3 vehicles would be reduced if the cryogenic ACPS were to be utilized. The average turnaround time for 3I would be reduced from 39 to 35 shifts. The average turnaround time for 3F would be reduced from 43 to 37 shifts. Reviewing the traffic model, launch rates, and nominal fleet sizes for Option 3, these reductions do not revise the number of required flight articles.

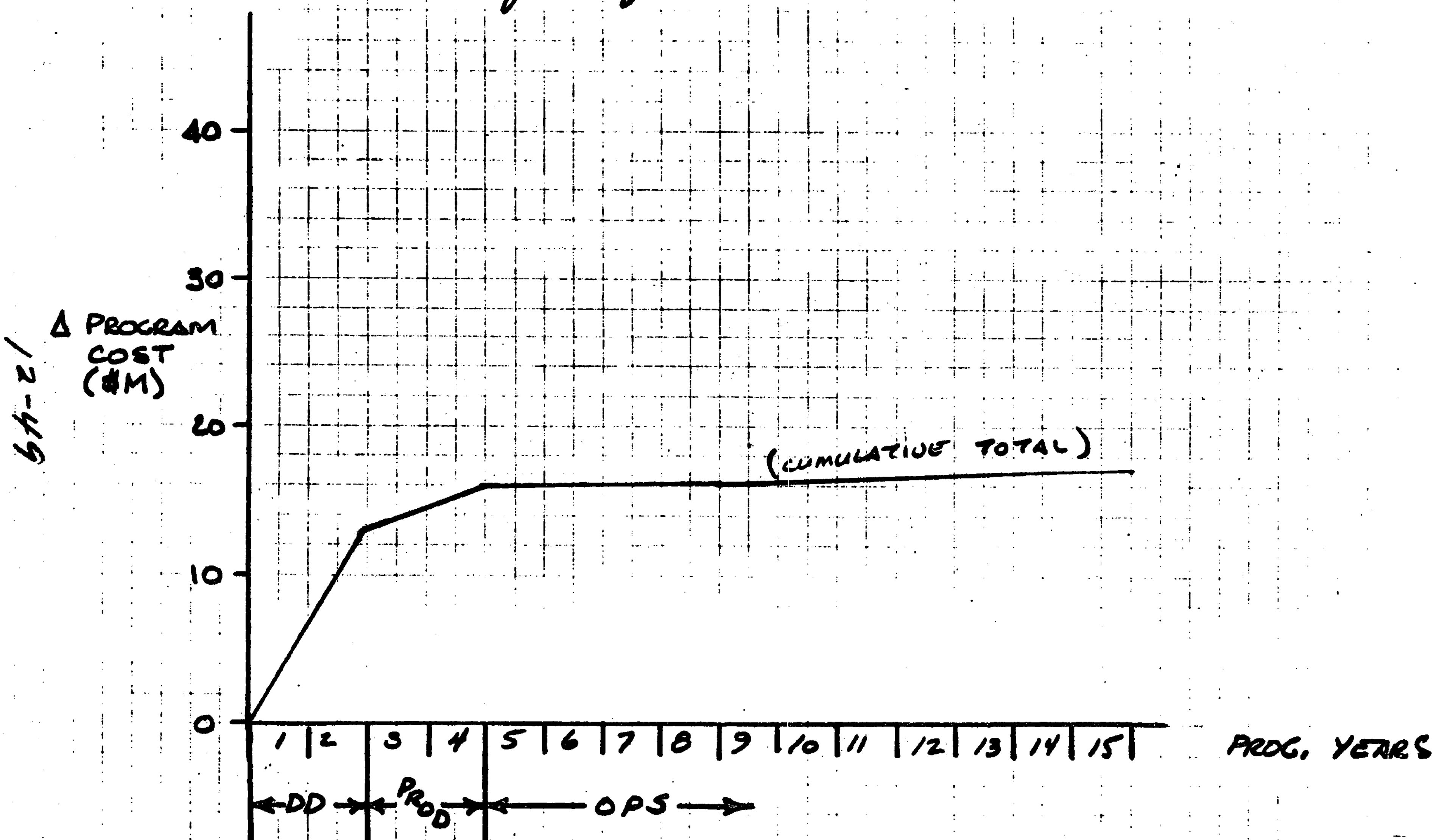
Summary

The ground operations impact which would result from incorporating cryogenic ACPS into the two configurations is summarized below.

	3I	3F
Maintenance Impact	+ $714,000	+ $1,580,000
GSE Impact	- $234,300	- $ 4,800
Crew Impact	- $225,000	- $ 875,000
Total Impact	+ $254,700	+ $ 700,200

In order to review the total impact to program costs, Figure 6.12.7-1 summarizes the delta cumulatige costs to DDT&E, Production, and Operations for Option 3 with cryogenic ACPS. As may be seen, this change results in a total cost increase of nearly $17 million to the Option 3 program.

Figure I
Program Option 3 Cost Impact
for Cryo APS



13.0 ON ORBIT SERVICING IMPACT

The on orbit servicing impact study was specified for performance on Option 2. The reader is referred to Vol 6, Option 2, section 13.0 for the detailed analysis.